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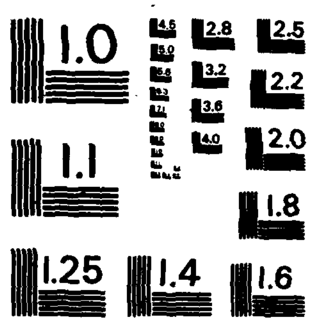

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EMERGENCY WARNING SYSTEMS

PART I

WARNING SYSTEMS — TECHNICAL REVIEW

FINAL REPORT

July 1983

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Prepared for:

FEDERAL EMERGENCY MANAGEMENT AGENCY
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This document is Part I of a two-part document series on emergency warning systems. An overview is given for typical warning system methods. Since the majority of warning systems use sirens, a major portion of this document deals with sirens and their technical specifications. Encoder and decoders used to control such systems are discussed, along with tone alert radios, DIDS, and factors concerning sound attenuation.

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TABLE OF CONTENTS

FOREWORD

This document is Part I of a two-part document on Emergency Warning Systems and is prepared for the Federal Emergency Management Agency (FEMA) and the Nuclear Regulatory Commission. Part I is a technical review of warning systems as they apply to the nuclear and natural disaster situation and, in particular, to nuclear emergencies in the 10-mile area around nuclear power plants. Data for this review included information on warning systems from documents prepared for various Federal agencies, information from test equipment manufacturers, and from most of the major manufacturers of various warning systems. Part II contains the guidelines for design and evaluation of warning systems.

EXECUTIVE SUMMARY

This document is Part I of a two-part report on Emergency Warning Systems. In Part I, the major types of warning systems are reviewed for their applicability toward nuclear power plant emergencies as well as nuclear attack or natural or man-made disasters. The systems examined included fixed sirens, mobile sirens (constituting the major portion of most warning systems), tone alert radios, power-line modulation/carrier current, automatic telephone dialers/switching devices, Decision Information Distribution System (DIDS, and National Warning System (NAWAS).

1.0 INTRODUCTION

This document is a technical review of a variety of warning systems that are, or can be, used for warning the general population for three different conditions. These conditions are:

- Natural disaster
- Nuclear attack
- Nuclear power station accident

The specific warning system types include:

- Fixed sirens
- Mobile sirens
- Automatic telephone dialers/switching equipment
- Modulated power line devices
- Tone alert radios
  - Beepers/pagers
  - NOAA/NWR service
  - SCA (Broadcast FM subcarrier)
  - Tone Alert (Plektron)
- DIDS (Decision Information Distribution System)
- NAWAS (National Warning System)

In addition to each of the warning systems listed, a separate section is given concerning encoders/decoders. These are devices that are used in some form in each of these systems to allow the warning devices to be commanded on or off and to perform other functions. They affect the security of a system by preventing false or inaccurate activation and vary in complexity. They are included since, in practice, the elimination of false activation is equivalent to system reliability. When a system is falsely activated it often is perceived as unreliable and, therefore, is an ineffective warning system.

Included in this document are four appendices. Appendix A provides siren manufacturers' specifications; Appendix B is a complete list of all NOAA radio stations along with supporting details; Appendix C includes specific details of an encoder and decoder used in a typical siren system; and Appendix D provides a detailed technical discussion of sound propagation and the decibel rating scales.

This information contained herein will form the technical basis for evaluating warning systems for a variety of conditions. It is intended to identify the operational and technical aspects of these systems and is a major reference document for the evaluation of warning systems. The technical data herein has been gathered from the major manufacturers of these warning systems. Other data from technical references has been gathered and reviewed along with documents that support the principal disciplines of these warning systems.

2.0 GENERAL DISCUSSION

The majority of present day warning systems, as used for warning the general population, are most often based upon some type of sound emitting device; i.e., sirens, whistles, horns, public address systems, etc. The sirens, whistles, horns, and public address systems emit a sound which is intended to be meaningful to the listener. This assumes that the listener knows what action to take based upon the type and tone of the sound, as well as the duration of the sound. In most cases, the sound means that either some action should be taken, such as return home, take cover, evacuate, or a radio or television should be listened to for further instructions.

Other warning devices use radio receivers of some type that are applied in a particular manner to warn a person to take some action and also provide the capability to give a specific message.

One major difference between the two warning system types just described (sound and radio) is that radio devices find their application as individual or small area warning devices, whereas sound types are applied on a geographical or area basis. The second major difference is that radio devices are most efficiently applied inside a home or building and sound devices are best suited for outdoor application. In practice, these devices are used for both indoor and outdoor warning. However, their respective ranges are reduced.

Another method of describing these two systems is to consider a radio controlled siren warning system. A practical example will have a central transmitter, such as that belonging to the local police or fire department, equipped with an encoder. This device modulates the transmitter signal with a code. This code is transmitted and received by a receiver device which interprets the code. The output from this receiver is then used to activate the siren. It is at this point that the systems can be divided. The receiver output circuit, instead of activating the siren, could be designed to turn on a light or bell, or activate additional circuitry to provide a tone to be followed by a voice message.

Of course, the siren, whistle or horn could be manually activated by a pushbutton or turned on via electrical connections from ordinary telephone lines. Hence, the telephone connection replaces the radio links and the telephone receiver is not a normal handset, but is replaced by a device similar to the radio receiver. This device interprets the command sent over the telephone lines (usually a tone or combination of tones) and provides the appropriate output circuitry to activate the siren.

Other methods of warning include various forms of telephone dialing/switching which include parts of the DIDS and NAWAS systems and a method of sending/receiving codes by modulation of the power lines on normal areawide power distribution networks.

The operational and technical features of these warning systems just listed are described in detail in the following sections and include:

- Sirens
  - Fixed
  - Mobile
- Tone Alert Radio
- Automatic Telephone Dialer/Switcher
- Modulated Power Lines Devices
- DIDS (Decision Information Distribution Systems)
- NAWAS (National Warning System)

3.0 SIRENS

Sirens are considered by many as outdoor warning devices as a matter of technical classification, yet in practice they serve as indoor and outdoor warning devices. The effectiveness of a siren is limited as an indoor warning device versus an outdoor warning device relative to the area coverage. When compared to area coverage, i.e., a siren outdoors might effectively warn people out to 7,500 feet from the source and out to 4,000 feet for those indoors. In this sense, the siren in fact is both an indoor and outdoor warning device. The major difference is that it is more difficult to measure the effectiveness of the indoor warning capability than it is to measure the outdoor warning capability. This is due to many factors such as:

- Type of building design and construction
- Time of day (asleep versus awake)
- Indoor activity such as music playing loudly or softly, etc.
- Time of year (i.e., summer, windows open; winter, windows closed)

All of these factors are simply added to those affecting sound propagation outdoors and include:

- Wind
- Rain/Snow/Fog
- Humidity
- Temperature Inversion
- Foliage
- Topography
- Ambient noise

All of the above factors actually affect the amount of sound power that propagates through the surrounding area. In other words, the sound power levels are attenuated by these factors and arrive at the listener's ear with a certain measurable sound level. For this level of sound to be recognized by the listener, the frequency of the sound must also be in the hearing range of frequencies of the human. This range is generally considered as being between a few hertz (cycles per second) up to approximately 15,000 hertz for an average person. Typical siren frequencies range between 300 to 1,250 hertz and can consist of one or several tones. A tone here generally means a specific frequency such as 500 hertz, which is considered as having a lower pitch on the musical scale than a 600 hertz tone. Thus, a dual-tone siren may have 500 and 600 hertz tones. This capability is considered as having a better "attention getting" capability than a single-tone siren. Of course a siren tone is not a pure tone (i.e., exactly 500 hertz and only 500 hertz), but rather a range of frequencies around a center frequency. This range can be referred to as the band which may include those frequencies varying from 450 to 550 hertz. This bandwidth is therefore 100 hertz (from 450 to 550).

3.01 FIXED SIRENS — GENERAL DISCUSSION

3.01.01 Signals and Tones

Sirens are designed to emit a sound. Their purpose generally is to alert people to turn on either their radio or TV for further information or to act immediately, depending upon the meaning of the siren signal. The classification of the type of sound output of a siren is called the signal. The frequency of the sound is sometimes referred to as the tone. There are three basic siren signals as classified by FEMA (formerly Defense Civil Preparedness Agency).

- Alert
- Attack Warning
- Fire

The alert signal is usually a steady tone (frequency) or dual tone (two frequencies) which may last for three minutes. Both tones are active for the entire time and comprise the alert signal.

The attack warning is a 3-minute wail; i.e., the sound or tone increases and decreases uniformly.

Fire is considered as a steady high/low or wailing high/low where the tone is a more abrupt change from high to low and vice versa.

In actual situations, these signals and their meaning vary, depending more upon what the local community is familiar with. For nuclear plant emergencies, the signal for attack warning is left on for 3 to 5 minutes. Note that where sirens have not been used locally and are then added for nuclear power plant warning, the actual signal definition can vary and is generally dependent upon state and local authorities to make the final determinations as to siren sound meaning. What does apply in siren stituations is that if a siren is intended for more than just nuclear plant emergencies (i.e., fire, tornado warning, etc.) it must have a multiple signal capability. Also, existing sirens that are in current use for fires may not be easily upgraded to perform the nuclear warning and therefore must generally be replaced with a new siren with the added signal capability.

3.01.02 Siren Types (Functional)

There are two major siren types, fixed sirens and mobile sirens. Mobile sirens are those generally associated with police, fire, and rescue vehicles, and are discussed in Section 3.02. Fixed sirens are those that are mounted on poles, building roofs, etc. and are used for a variety of warning functions. The manner in which the siren output sound is produced is from either electromechanical means or electronically.

3.01.03 Electromechanical Sirens

An electromechanical siren might use an electrical motor with a rotor-stator arrangement. Here the rotor is attached to the shaft of the motor which rotates at high speed, forcing air through the stator. This arangement produces the siren sound. The stator design or baffal arrangements are used to vary the siren sound and produce more than one tone (frequency). Another, similar method is to use an air compressor to force air through various stator/baffle arrangements to produce the siren sounds.

Electromechanical sirens are the most widely used siren types today and have been in use since the early 1900's. Typical output power levels for these sirens range from 85 to 135 dBC and all operate on conventional AC electrical power.

3.01.04 Electronic Sirens

Fixed electronic sirens produce their output sound similar to that of a public address system except that a siren sound is produced. However, most electronic sirens also have a public address capability. These sirens differ from electromechanical sirens in that mechanical or rotating parts are not required. Sirens of this type can be described as mostly solid state units and most are designed to operate on batteries. In this case, heavy duty type (100 amp hour ratings or better) batteries commonly found in trucks are used as primary power for these systems.

The electronic sirens produced in the last 3 years now have output power capabilities equal to that of some electromechanical sirens. This has become possible with the advances in the current carrying capacity of solid state amplifiers/drivers. Most of the sirens in this catagory have output power levels ranging from 106 dBC to 126 dBC.

3.01.05 Siren Types (Physically)

Physically, there are two types of sirens, directional and non-directional. Directional implies a siren with a single horn that is rotated. These sirens are generally referred to as rotating directional. Sirens of this type usually have output power in the 123 to 128 dBC range. The rate of rotation can be selected but is usually 3 to 4 revolutions per minute.

The coverage of a rotating directional siren is a function of the design of the siren horn assembly. Nominal coverage is a total beam width of 30° to 40° in the horizontal plane. The vertical plane beam width is usually less than 30°.

The non-directional siren is often referred to as omni-directional and has a uniform sound output on a 360° horizontal plane. Most of these types, have a lower output power capability than directional and have a smaller coverage area but, when used, provide continuous sound power in a 360° plane.

3.01.06 Output Power/Coverage

Siren output power levels are rated as measured on the dBC scale at 100 feet from the source. Most rotating directional sirens have output power levels from 123 dBC to 128 dBC. Omni-directional sirens operate from approximately 100 dBC to 120 dBC. (Note that there are exceptions in each case.) To calculate effective siren coverage, it is standard practice to assume that the siren sound level should be approximately 9 dB to 10 dB above ambient background noise levels to be noticeable to a preoccupied person. As a general rule of thumb, average rural background noise levels are 50 dB or higher, while urban background noise is 60 dB or higher. This means that the siren sound pressure level, to be noticeable in a rural environment, should be at least 60 dB or higher; in the urban environment it should be 70 dB or higher.

To calculate the siren coverage area, a 10 dB loss per distance doubled is a general rule of thumb. For a siren with an output power level of 125 dBC, assume approximately a 5,000-foot radius coverage at 70 dBC. This, of course, assumes that the siren is mounted above surrounding buildings (roof top) and is not obstructed in any other manner. Also assume coverage is line of sight and that sound is attenuated greater than 10 dB per distance doubled when interrupted by objects such as hills, buildings, etc. This coverage is also affected by heavy foliage and severe weather and wind. Upwind from a siren results in reduced coverage on windy days and downwind is hardly affected and, in fact, can have an additive effect.

3.01.07 Input Power Requirements

Input power requirements vary a great deal, especially between electronic sirens and electromechanical sirens. Electronic sirens operate from batteries only; usually two 12-volt batteries connected in series to derive 24 vdc. Hence, the primary power requirement for an electronic siren is 24 vdc at a nominal

90 ampere operating current. These sirens cannot operate without batteries (24-vdc power) and therefore have a maximum operating time dependent upon the charge level and capacity of the batteries. For most electronic sirens, this is a maximum of 30 minutes operating time. Most of these systems' batteries are connected to a 115 VAC single-phase source battery charger which is used to keep the batteries at full charge. However, the 115 VAC source cannot be used to operate the siren.

Electromechanical sirens, on the other hand, operate only from primary AC power sources. This can range from 115 VAC single-phase up to 480 VAC 3-phase, dependent upon the power requirements of the motors used in the siren. The power requirements for those sirens in the 115 dBC range and higher is greater than that found in a typical house outlet. For example 115 VAC single-phase systems may require more than 150 amps for initial starting current. In fact, the more powerful electromechanical sirens operate more efficiently on 3-phase AC power since starting and operating currents are high. This also results in a greater possiblity that the power requirements for a siren in a remote area cannot be met with the existing power distribution networks and requires additional power lines to accommodate such installations. Furthermore, since the operating currents are high and the unit operates on AC voltages, these sirens cannot be operated from commercially available batteries. Consequently, most electromechanical sirens are subject to those problems associated with power outages. Backup power for most electromechanical sirens would require a motor generator type of arrangement due to the power requirements that cannot be satisfied by batteries.

3.01.08 Siren Activation

Siren activation is accomplished in several ways including:

- Direct electrical or mechanical switches
- Via telephone lines
- Radio transmission
- Programmed timers
- Combinations of the above

The most economical method for large siren systems, such as those around nuclear power plants, is radio activation. This is a very flexible type of system where more than one center can activate the sirens and it can be done on a selective basis by using coded signals in the transmission-reception process or on a group basis where all or a group of sirens are activated.

The transmitter for this type of activation is usually the local police, fire, rescue, or local government frequency. The actual piece of equipment attached to the transmitter is the encoder. Encoder implies that a code is modulated on to the transmitted signal. The receiver at the siren includes the decoder and is pre-assigned to a specific code or address. (Refer to the Encoder/Decoder Section.)

Direct activation is accomplished usually by a pushbutton or toggle switch. The duration of the siren output is usually controlled by a timer. In practice, just about any method can be used for system activation and the system size and operational requirements, in effect, dictate the activation methods.

3.01.09 Siren Coverage

Siren coverage for any particular siren is determined by many factors, most of which are related to the principals of sound propagation and the ability of the human ear to detect such siren sounds. Extensive research in this area has been performed. As a result of this research, a document entitled "Outdoor Warning Systems Guide" by Bolt, Beranek and Newman, Inc., has been published under a contract funded by the federal government.

This document has effectively produced guidelines for determining sound propagation characteristics which are used extensively by siren manufacturers, consultants, and engineering firms engaged in the design and installation of siren warning systems. There are other documents as well, that provide principles for sound propogation and measurement. Appendix D, included here, contains Chapter 2, "The Physical Properties of Noise" from the document entitled "Acoustic Noise Measurements," by Bruel and Kjaer, January 1979. This document, in principal, agrees with the "Outdoor Warning System Guide." From these documents the "rules of thumb" that can be applied to siren coverage/sound propagation are as follows:

(1) Theoretically, as sound travels, 6 decibels of signal loss is incurred for each doubling of distance. In practice, where many obstacles serve to attenuate sound propagation, assume a 10 decibel signal loss for each distance doubled.

(2) A sound gets the attention of the listener when it is 8 to 10 decibels above the background (ambient) noise level.

(3) Average background noise levels in a rural type environment may be as low as 50 decibels; in an urban/city type environment, 60 decibels. However, generally those levels vary and more often are higher than 50 and 60 decibels.

(4) On average, the largest contributor to background noise levels is automotive traffic and other transportation systems.

(5) Assume that sound travels in a direct line (line of sight) and therefore siren coverage cannot be expected to be effective in valleys and around mountains.

(6) Adverse weather, especially wind, affects siren coverage.

(7) Mount sirens above tree tops and building tops for best coverge. (Note mounting a siren on mountain or hill tops does not provide coverage to surrounding valleys unless the siren is so directed.)

The following table shows the typical siren coverage of a 125 dBC siren using the above guidelines:

Initial Output Power Level (dBC)	Distance from Siren (feet)	Power Level (dB)
125	100	125
125	200	115
125	400	105
125	800	95
125	1,200	90
125	1,600	85
125	2,400	80
125	3,200	75
125	4,800	70
125	6,400	65
125	9,600	60

The previous example shows the 10 dB loss per distance doubled which is a general design guideline. There are further refinements to this depending upon whether the area is rural or urban. Basically, rural area background noise levels are nominally 50 dB to 60 dB and 60 dB and higher for urban areas. This translates to 70 dB or 4,800 feet radius circles for a background noise level of 60 dB. Other factors, such as buildings and mountains, must then be accounted for to finalize siren design coverage.

3.01.10 Siren Manufacturers

There are four major siren manufacturers in the United States and one West Germany firm that recently opened an office in California. The United States firms include:

- Alerting Communications of America; a division of Biersach and Niedermeyer Co., Mequon, Wisconsin
- Federal Signal Corporation, Blue Island, Illinois
- Sentry, Canon City, Colorado
- Whelen Engineering Co., Deep River, Connecticut

The West Germany firm opening an office in California is Raytek Inc., which is part of the Hoerman Group. As of July 1983, their sirens can be purchased from West Germany.

The above-listed United States firms are known to have installed or are installing sirens at various nuclear plants. A complete list of all sirens manufactured by the U.S. firms are given in the following tables and includes technical specifications for each. Table 1 lists siren model numbers by manufacturer in alphabetical order and by type, and Table 2 lists all sirens in descending order of output power level. The data sheets in Appendix A list the technical specifications of each siren by descending output power level for each of the four manufacturers listed above. Refer to this list of tables for specific make and model number.

TABLE 1. SIRENS BY TYPE AND MANUFACTURER IN DESCENDING OUTPUT POWER LEVEL ORDER

OMNI-DIRECTIONAL

Electromechanical

Manufacturer	Output	Model
A.C.A.	125 dBC	Cyclone
A.C.A.	119 dBC	Super Banshee
A.C.A.	116 dBC	Banshee, single tone
A.C.A.	112 dBC	Banshee, dual tone
A.C.A.	112 dBC	Screamer S-10
A.C.A.	108 dBC	Screamer S-7.5
A.C.A.	105 dBC	Screamer S-5
A.C.A.	101 dBC	Screamer S-2.5
Federal Signal	115 dBC	STH10A
Federal Signal	115 dBC	STH10B
Federal Signal	115 dBC	STL10A
Federal Signal	115 dBC	STL10B
Federal Signal	115 dBC	3T22A
Federal Signal	115 dBC	3T22B
Federal Signal	107 dBC	5A
Federal Signal	107 dBC	5B
Federal Signal	102 dBC	2
Sentry Siren	123 dBC	10V2T
Sentry Siren	123 dBC	10V2T-3S
Sentry Siren	115 dBC	10V
Sentry Siren	112 dBC	5V
Sentry Siren	107 dBC	3V8

Electronic

Manufacturer	Output	Model
A.C.A.	115 dBC	Altertronic 4000
Federal Signal	115 dBC	SiraTone EOWS*115

Manufacturer	Output	Model
Whelen Engineering	115 dBC	WS-2500
Whelen Engineering	112 dBC	WS-2000-112
Whelen Engineering	109 dBC	WS-2000-109
ROTATING-DIRECTIONAL		
Electromechanical		
A.C.A.	135 dBC	Penetrator 50
A.C.A.	130 dBC	Hurricane
A.C.A.	127 dBC	Allertor
A.C.A.	125 dBC	Penetrator 10
A.C.A.	123 dBC	Howler
Federal Signal	127 dBC	Thunderbolt 1000A
Federal Signal	127 dBC	Thunderbolt 1000B
Federal Signal	125 dBC	Thunderbolt 1000AT
Federal Signal	125 dBC	Thunderbolt 1000BT
Federal Signal	125 dBC	Thunderbolt 1003A
Federal Signal	125 dBC	Thunderbolt 1003B
Federal Signal	123 dBC	Thunderbolt 500A
Electronic		
A.C.A.	125 dBC	Aletronic 5000
Federal Signal	126 dBC	SiraTone EOWS*812
Federal Signal	124 dBC	SiraTone EOWS*612
Federal Signal	122 dBC	SiraTone EOWS*408
Whelen Engineering	115 dBC	WS-2000R
Whelen Engineering	124 dBC	WS-3000
CLOVERLEAF		
Electromechanical		
Sentry Siren	115 dBC	M10
Sentry Siren	112 dBC	M5

TABLE 2. SIRENS BY OUTPUT POWER LEVEL IN DESCENDING ORDER

Output	Type	Manufacturer	Model
135 dBC	Electromechanical, Rotating-directional	A.C.A.	Penetrator 50
130 dBC	Electromechanical, Rotating-directional	A.C.A.	Hurricane
127 dBC	Electromechanical, Rotating-directional	A.C.A.	Allertor
127 dBC	Electromechanical, Rotating-directional	Federal Signal	Thunderbolt 1000A
127 dBC	Electromechanical, Rotating-directional	Federal Signal	Thunderbolt 1000B
126 dBC	Electronic, Rotating-directional	Federal Signal	SiraTone EOWS*812
125 dBC	Electronic, Rotating-directional	A.C.A.	Alertronic 5000
125 dBC	Electromechanical, Rotating-directional	A.C.A.	Penetrator 10
125 dBC	Electromechanical, Rotating-directional	Federal Signal	Thunderbolt 1000AT
125 dBC	Electromechanical, Rotating-directional	Federal Signal	Thunderbolt 1000BT
125 dBC	Electromechanical, Rotating-directional	Federal Signal	Thunderbolt 1003A
125 dBC	Electromechanical, Rotating-directional	Federal Signal	Thunderbolt 1003B
125 dBC	Electromechanical, Omni-directional	A.C.A.	Cyclone
124 dBC	Electronic, Rotating-directional	Whelen Engineering	WS-3000
124 dBC	Electronic, Rotating-directional	Federal Signal	SiraTone EOWS-612
123 dBC	Electromechanical, Rotating-directional	A.C.A.	Howler
123 dBC	Electromechanical, Rotating-directional	Federal Signal	500A
123 dBC	Electromechanical, Omni-directional	Sentry Siren	10V2T
123 dBC	Electromechanical, Omni-directional	Sentry Siren	10V2T-3S
122 dBC	Electronic, Rotating-directional	Federal Signal	SiraTone EOWS*408
119 dBC	Electromechanical, Omni-directional	A.C.A.	Super Banshee
116 dBC	Electromechanical, Omni-directional	A.C.A.	Banshee, single tone

Table 2, Continued

Output	Type	Manufacturer	Model
115 dBC	Electromechanical, Omni-directional	Federal Signal	STH10A
115 dBC	Electromechanical, Omni-directional	Federal Signal	STH10B
115 dBC	Electromechanical, Omni-directional	Federal Signal	STL10A
115 dBC	Electromechanical, Omni-directional	Federal Signal	STL10B
115 dBC	Electromechanical, Omni-directional	Federal Signal	3T22A
115 dBC	Electromechanical, Omni-directional	Federal Signal	3T22B
115 dBC	Electromechanical, Omni-directional	Sentry Siren	10V
115 dBC	Electromechanical, Cloverleaf	Sentry Siren	M10
115 dBC	Electronic, Omni-directional	Federal Signal	SiraTone EOWS*115
115 dBC	Electronic, Omni-directional	Whelen Engineering	WS-2500
115 dBC	Electronic, Rotating-directional	Whelen Engineering	WS-2000R
112 dBC	Electromechanical, Omni-directional	A.C.A.	Banshee, single tone
112 dBC	Electromechanical, Omni-directional	A.C.A.	Screamer S-10
112 dBC	Electromechanical, Omni-directional	Sentry Siren	5V
112 dBC	Electromechanical, Cloverleaf	Sentry Siren	M5
112 dBC	Electronic, Omni-directional	Whelen Engineering	WS-2000-162
109 dBC	Electronic, Omni-directional	Whelen Engineering	WS-2000-109
108 dBC	Electromechanical, Omni-directional	A.C.A.	Screamer S-7.5
107 dBC	Electromechanical, Omni-directional	Federal Signal	5A
107 dBC	Electromechanical, Omni-directional	Federal Signal	5B
107 dBC	Electromechanical, Omni-directional	Sentry Siren	3V8
105 dBC	Electromechanical, Omni-directional	A.C.A.	Screamer S-5
102 dBC	Electromechanical, Omni-directional	Federal Signal	2
101 dBC	Electromechanical, Omni-directional	A.C.A.	Screamer S-2.5

3.02 MOBILE SIRENS

Mobile sirens, for this discussion, are those used by police, fire, and rescue type vehicles. These mobile sirens are often used in siren warning systems to supplement the existing system where certain areas have a very low population density and, as a result, it is not cost effective to place fixed sirens in such areas. Of course, mobile sirens have other warning applications and may serve as the primary warning system in small populated areas and for areas such as recreational parks where seasonal use of such areas makes a fixed siren system less cost effective.

There are several types of mobile sirens. A partial list includes those that have full 360° coverage; those that are directional with a beam directed forward, or to the sides, or forward and rearward. Actually, the direction is a function of how the siren is mounted and the most common mounting scheme is for forward sound projection.

Mobile siren output power levels, on average, range from 100 to 116 dB at 6 or 10 feet. (Note that fixed sirens are rated at 100 feet.) Note, however, that this is not a required standard but rather the common method used by several manufacturers.

In calculating mobile siren coverage, all the factors that affect fixed sirens must be considered as well as the following:

- Vehicle speed – This affects the amount of time that the individual is exposed to the maximum sound and therefore may affect his/her interpretation of what action to take.
- Directional/omni-directional – A forward directional siren giving maximum coverage to the area in front of the vehicle may not be as effective for warning individuals in a home compared to warning individuals in vehicles on the road.
- Listener interpretation – Mobile sirens are most often associated with emergency vehicles requiring clearance on the roadway. Where these sirens are used for warning individuals for other purposes, a public address capability is often required to make this warning method effective.

In the preceding paragraph, it is noted that mobile sirens, when used as a warning device, very often require a public address capability. This is common to many police and fire service vehicles and therefore is a prime consideration in determining the effectiveness of mobile sirens when used as warning devices for the nuclear and natural disaster situations.

From a technical perspective, it can be shown that a mobile siren with a commonly stated output power level of 115 dB cannot provide the same coverage as that of a 115 dB fixed siren (refer to Appendix D for dB scale comparisons). The following list shows the expected output power levels from a mobile siren (directional and omni-directional) in decibels.

Mobile Directional Siren		Mobile Omni-Directional Siren	
Sound Power Level (dB)	*Expected Sound Power Level (Feet)	Sound Power Level (dB)	*Expected Sound Power Level (Feet)
115	10	115	6
105	20	105	12
95	40	95	24
85	80	85	48
75	160	75	96
65	320	65	192
55	640	55	384

*Assumes a 10 dB signal loss per distance doubled.

4.0 TONE ALERT RADIO

There are a variety of radio devices that can be classified as tone alert radios. Tone alert radio is defined here as a radio receiver that is electrically activated but provides no visual or audible output until a code, unique to each radio, is received. Upon reception of the proper code (also referred to as the address), additional circuitry in the radio receiver is activated. Actuation of this additional circuitry allows the radio to receive a message which can activate an audible tone (hence the name tone alert), provide a voice message or a printed message, cause a light to be turned on, or any combination of the above. Generally, the signal that the radio receives is transmitted from a central point. That part of the signal that "turns on" the radio receiver is a special code and the device that generates this code is generally called an encoder. The encoder output, in fact, modulates the transmitter with the code or address or other information. The encoder can be compared to a microphone. A microphone translates a voice or music into an electrical signal to modulate a transmitter whereas the encoder modulates an address into a transmitted signal.

There are a variety of tone alert radio systems which vary slightly in the actual method of signal transmissions and all are not true "tone alert" devices. Those considered here include the following:

- Beepers/Pagers— These are probably the purest form of tone alert radio. Beepers, also known as pagers, are generally used commercially as a device to alert a person to respond to a call. They are battery operated, portable devices, often attached to a belt, etc., and emit a high pitched tone audible to the person with the device. They operate in a frequency band (range of frequencies) that is assigned by the FCC for commercial use.

- NOAA Radio — NOAA Weather Radio is a service of the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce. It provides continuous broadcasts of the latest weather information directly from National Weather Service offices. Taped weather messages are repeated every four to six minutes and are routinely revised every one to three hours, or more frequently if needed. Most of the stations operate 24 hours, daily.

  The radio receivers for NOAA radio are commercially available in a variety of stores selling electronic equipment. They can be purchased with a variety of options including that of a tone alert capability. This is especially useful to those who subscribe to this kind of information since they may be interested only in severe weather forecasts. Boaters, truckers, farmers, public safety officials, etc. find this a valuable service as well as anyone who may wish to know the latest weather forecast.

During severe weather National Weather Service forecasters can interrupt the routine weather broadcasts and substitute special warning messages. At this time, the forecasters can also activate specially designed warning receivers. The receivers either sound an alarm indicating that an emergency exists, alerting the listener to turn the receiver up to an audible volume; or, when operated in a muted mode, are automatically turned on so that the warning message is heard.

The actual messages given are for the area covered by the radio transmitter. There are approximately 360 NOAA stations currently in operation. A complete list of these stations is found in Appendix B. Their coverage area throughout the U.S. could reach approximately 90 percent of the population, assuming all have receivers.

- Tone Alert, (Plektron), Radio Tone Alert — Tone alert radios are commonly used in public service areas. Most prominently are the volunteer fire departments. Plektron, often used as a generic term, is the brand name of one of the companies that manufacture tone alert radio devices. Many other companies including General Electric, RCA, Motorola, Fisher-Pierce, as well as others, manufacture such units. These radios are most commonly found in the home using conventional power, although battery back-up is common. They usually provide a voice capability as well as an alerting tone or light that is activated by the coded transmission. The voice capability is often used to give a specific message to the user.

- FM Broadcast Subcarrier Technique — The FCC Subsidiary Communication Authorization (SCA) has allowed commercial and noncommercial broadcast stations to transmit information on a subcarrier of the main FM broadcast signal. The most prominent use of this technique is the transmission of background music, storecasting, weather forecasts, etc. The FCC regulation requires that this service be of interest to a portion of the public. It requires a specially equipped radio that can properly demodulate the FM subcarrier and often is a radio effectively tuned to only one station. Special circuitry is often added to these radios to allow for a standby mode or muted mode of operation and is activated by a code or address. Units of this type therefore could be used for the warning function.

The previous paragraphs provide an introduction to the most common tone-alert radios in operation. Each has its own special application which depends on a variety of factors including intended use, cost, system control, etc. Following is a description of the most important functional areas of these devices and where each of the previously listed units are most effective.

4.02 TONE ALERT - GENERAL DISCUSSION

Tone alert radios perform many functions. The most important ones for this discussion include the warning and communications functions. However, the practical use of these systems is restricted by various FCC rules and regulations as well as other factors of local concern. These factors include the following:

- Functions Performed
- FCC Rules and Regulations
- Normal System Use
- Coverage/Frequencies Used

The systems to be discussed include:

- Beepers/Pagers
- NOAA Radio
- Tone Alert (Plektron) Radio Tone Alert
- FM Broadcast

4.02.01 Beepers/Pagers

4.02.01.01 Functions Performed — Beepers or pagers most often serve as a warning or alerting device by emitting a tone when the address of the unit is received. Units of this nature seldom provide a capability beyond a tone alert. Their function, when activated serves to notify the person to perform a function, e.g., call a number, alert others, etc. This function normally has been predetermined so that the user "knows" what action to take when the tone is heard. Beepers (pagers) are often used by service personnel and security personnel who are away from telephones or other communications devices and must be notified immediately, regardless of their location.

4.02.01.02 <u>FCC Rules and Regulations</u> — The FCC rules and regulations for commercial beepers and pagers do not restrict the use of these commercially available devices for warning purposes. The same applies to this identical service also provided by common carriers (telephone companies, etc.).

4.02.01.03 <u>Normal System Use</u> — Beepers and pagers are generally used for paging services which are provided by private companies or by telephone companies. The user pays a monthly rental fee or can purchase the device. Each pager has a code which activates it. This code is generally keyed to a specific telephone number where the caller dials a telephone number corresponding to the person carrying the device. More than one device could have the same number. Dialing the number activates one or more centrally located transmitters which send out the coded signal to activate the device. The system does not normally provide voice messages and does not have two-way communications.

4.02.01.04 <u>Coverage and Frequencies Used</u> — Commercial and common carrier paging systems on average, provide for a nominal 40 miles radius coverage from the transmitter. Operating frequencies can be any of those in the low band, high band, or UHF band that are assigned to common carriers or to the Private Land Mobile Services.

4.02.02 <u>NOAA Weather Radio</u>

4.02.02.01 <u>Function Performed</u> — NOAA Weather Radio (NWR) provides "continuous broadcasts of the latest weather information" directly from National Weather Services offices. These messages are taped and repeated every 4 to 6 minutes. This may be updated hourly, every 3 hours, or sooner, as required.

4.02.02.02 <u>FCC Rules and Regulations</u> — There are seven frequencies assigned to NWR and are government assigned frequencies. Generally, this means that the user agency can use these frequencies as required without any additional restrictions by the FCC.

4.02.02.03 Normal System Use — The NWR broadcasts continuous weather information. During severe weather conditions, the National Weather Service forecasters can interrupt the routine messages, activate the coded warning signal to demute those receivers so equipped, and broadcast special warning messages. The use of this system for broadcasting the warning of a nuclear attack as well as for weather, has been established in a January 1975, White House policy statement. Furthermore, agreement has been reached between NRC, FEMA, and NOAA regarding the use of this service for warning around nuclear power plants. In this case prerecorded messages can be established for various conditions, and broadcast as required. Formal arrangements between NOAA and the local EOC and local officials are then made to implement this aspect of the NOAA system.

4.02.02.04 Coverage/Frequencies Used — Most NOAA radio stations operate on frequencies of either 162.40, 162.475, or 162.55 MHz. Four other frequencies are available for future use and include 162.425, 162.450, 162.50, and 162.525 MHz. The coverage area for a typical station ranges to a nominal 40 mile radius. A complete list of NOAA weather radio stations, their locations, and transmitter output power levels is contained in Appendix B.

4.02.03 Tone Alert (Plektron) Radio Tone Alert

4.02.03.01 Function Performed — Typical radio tone alert devices operate in the standby or muted condition. Reception of the proper code (address) activates the device, usually emitting an attention-getting tone which is followed by a voice message. The units can be portable battery-operated devices or operate from conventional AC power (115 VAC). These units, almost always are a receive-only device and are used to (a) alert a person to listen for a message to follow, or (b) provide a capability to give explicit messages to one person or a group of people, usually associated with emergency action procedures.

4.02.03.02 FCC Rules and Regulations — Tone alert radios are often found to operate on police, fire, local government, forest service, and rescue service frequencies. These frequencies may be those of the normal day-to-day operating channels of these agencies. However, since the radios are a receive-only device, few restrictions are applied to such use. They operate in whatever band of frequencies are assigned to the user agency.

4.02.03.03 Normal System Use — Tone alert radios are often found in applications for alerting volunteer firemen, certain public officials, heads of large public and private institutions (hospitals, nursing homes) as well as many others. Control of the tone alert system is dependent upon the agency issued the operating license used by the system. Usually, the tone alert function is a secondary function of the operating frequency since usage is limited to emergencies. Occassionally, other agencies of the civil defense or disaster services type use frequencies assigned to them for this purpose only. A typical volunteer fire system would have all receivers assigned the same code so that all volunteers could be alerted simultaneously. By adding additional codes, other receivers could be added, expanding system capability.

4.02.03.04 Coverage/Frequencies Used — Most tone alert devices use the already assigned frequencies of the various public agencies listed above. These frequencies therefore cover the entire range of frequencies assigned to such agencies including those in the low-band, high-band, and UHF ranges. Typical average coverage areas can range from 15 to 40 miles radius. Greater range may be accomplished when transmitter repeaters are used.

4.02.04 FM Broadcast

4.02.04.01 Function Performed — Commercial FM broadcast stations could implement a tone-alert and voice warning capability with slight modifications to commercially available equipment. Such equipment would be designed for this specific purpose.

4.02.04.02 FCC Rules and Regulations — The FCC allows for FM broadcast stations to add subcarriers to their regular main channel signal. The commission states that those programs of a broadcast nature may be background music, storecasting, detailed weather forecasting, special time signals, or other material of a broadcast nature expressly designed and intended for business, professional, educational, trade, labor, agricultural, or other groups engaged in any lawful activity.[1]

4.02.04.03 Normal System Use — FM broadcast stations obviously provide the entertainment, news and other services common to day-to-day AM and FM broadcast stations. The subcarrier modulation techniques are, in fact, common to those subscribers (background music, storecasting, etc.) who use such services.

4.02.04.04 Coverage/Frequencies Used — System coverage is limited to that of the FM broadcast station which is a nominal 40-60 mile radius from the transmitter. The frequencies would include that of the FM broadcast band, (88.1 MHz to 107.9 MHz).

[1] McMarten SCA for FM Broadcast Stations, Leonard E. Hedbund, Vice President, Research and Development, McMartin Industries, Inc., Omaha, Nebraska.

5.0 AUTOMATIC TELEPHONE DIALERS

The use of automatic telephone dialers for warning individual personnel or the general population can be implemented by a variety of equipment. However, first the terms telephone dialer and automatic switching equipment will be defined, both from a functional and technical point of view and from a generic point of view.

5.01 TELEPHONE DEFINITION

Dialing a telephone is a functional step taken by one person to contact another. The dialing action serves to make a series of electrical connections via the switching equipment in the telephone exchange office. Obviously, the touch-tone type of telephone completes the same circuits except for the dialing action. In this case dialing is not done but rather the electrical connections are made by depressing pushbutton switches (touch-tone switches). To automatically perform the same procedures described above, an automatic telephone dialer could be attached to the regular telephone. Commercially available units of this type are preset to "dial" from 1 to 10 or more telephone numbers. Note that these numbers (or stations as they are referred to by telephone companies) are dialed sequentially and only one number can be dialed at a given time. Units of this type find applications in business offices where the dialers are preset to call (or dial) the most often used numbers. These types of units have only limited capability as warning devices since the number of stations to be called in emergencies may well exceed 100 or more stations and the time to call one station requires almost the same amount of time as manual operations.

5.02 AUTOMATIC SWITCHING EQUIPMENT

Automatic switching equipment, however, is commercially available. This equipment connects directly to the telephone exchange equipment and can call 100, 1,000 or more stations simultaneously. Special ring conditions can be applied to such equipment as well as tape recorded or manually entered voice messages.

Some manufacturers will refer to systems of this type as "multi-station ring down" or a "hot line" system. In either case, the calling party has only to lift the handset to initiate a call or warning, depending upon the configuration.

Typical applications for telephone systems of this type may include the following:

- Fire warning for high rise buildings
- Industrial accident warning in or around chemical and nuclear facilities
- Weather warning
- Emergency warning/evacuation in small communities and remote areas where outdoor warning systems might not be effective

These systems make use of the existing telephone equipment installed in the house or business place and do not require any special installation or hookup in such areas. Most all equipment installation is performed at the telephone company's central office where switching equipment, or PBX switching equipment, is located.

> Note: PBX is an abbreviation for Private Branch Exchange and refers to telephone equipment which may be located on the premises of a business, etc. It may be owned or leased from a public or private telephone company. Telephone trunk lines connect the PBX to the telephone company switching equipment.

Many of the systems installed may be operated one-way (listen only), two-way (listen and talk), or may include a special ring for alerting purposes in addition to the above. The variety of ringing combinations varies from one company to another. However, these systems may be set to ring the receiving telephone in the normal manner or to let it ring continuously or provide a special ring. Special rings often used may include ½ seconds on and 2 seconds off, continuous ringing, or various other combinations as required.

How the ringing is initiated is of course a function of how the system is installed. Following is an example of a typical telephone alerting system.

Assume a system used for alerting 100 stations or locations where the central control for the system is located in the dispatcher's office of a county police and fire department. The stations (location) for those on the system include all of the volunteer fire fighters (40 for example), all police (40), and all local government officals (20; town mayor, county commissioners, fire and police chiefs, etc.). Such a system, being controlled from the dispatch center, would have a sectional capability to alert and provide a message to only the volunteer fire fighters or the police or the public officials or any combination of the above. In addition the system could be designed to provide one-way only (alert and voice message) to the fire and police yet provide two-way communications with the public officials. In any of the alerting situations, the dispatcher might lift a phone handset, depress a few switches, and immediately alert those desired within a minute or less. Of course other features can be added. In cases where the telephone is in use for daily business, features such as providing a special ring to the user that an emergency message is emminent can be easily implemented. Conference call capability can also be added. In addition, at the station end, instead of a regular telephone, a device to decode the warning can be added which in turn might activate a bell, siren, horn, etc.

6.0 MODULATED POWER LINES

Power lines used for distribution of electrical power carry a variety of voltage and current levels. This power originates at the power station and is sent to various substations where transformers reduce the voltage levels to that suitable for local distribution. Local distribution transformers are used to bring the sub-station voltage levels down further to those levels required for domestic use. These levels are the common 115 to 230 volts AC found at electrical outlets in a typical home. The sequence described above is the normal method used for power distribution. However, the power lines can also be used to transmit information by applying a frequency, known as a carrier, to the power line and then to modulate this carrier. Modulation in this instance is, in fact, the addition of data or information to a steady frequency or carrier. Extracting this information is known as demodulation. The information at the receiver (demodulator) is then used to perform a function such as turn on a water heater, activate a transmitter to read the meter, ring a bell, etc.

The process described above is a simplified description of a warning technique termed the Distribution Line Carrier System that is currently in use by the Westinghouse Corporation.

Actually, this power line modulation technique was developed many years ago to be used in applications such as power line meter reading, water heater control, etc. However, a variety of technical problems were not solved until recently. One of those problems concerned the amount of electrical noise inherent in a power distribution system; others included the signal losses incurred when power transformers were on line, as well as many other technical problems that affected reliable data transmission. Problems such as these affect the transmission and reception of the signals and therefore the ability to properly demodulate (correctly identify the coded signals) and respond to the signals. In any case, this modulated signal is used to perform a function. Note that this system is, effectively, a two-way communications system with the capability to perform a function based upon the make-up (in this case data pattern) of the modulated signals.

The carrier frequencies used may vary from system to system and may nominally range from 10kHz to 60kHz. Usually, testing is required on the actual power distribution system to select the best frequency range for the carrier and to keep the data error rates to acceptable levels (98 percent or better).

Modulation of the carrier is handled by a centrally located computer with standard communications devices. This allows for rapidly sending and receiving data automatically to many users (several thousand), and easily allows for a variety of message formats. Systems of this type can actually perform as a warning system as well as a meter reading device, a control device, etc. Note that control for warning systems is accomplished by providing a contact closure at the electrical meter which is connected to a horn or small siren. A contact closure is the electrical equivalent of a switch. Once the closure (usually a relay contact) is made, the device is turned on. The device is turned off by the proper transmission of a different signal pattern.

Where meter readings are taken, the meter has a transmitter capability, and therefore a modulation capability. The proper signal is sent from the central computer; received and demodulated (recognized) at the meter. The meter then modulates the carrier that it transmits. This modulation is the data representing the meter's condition or reading at that time. This is read (demodulated) at the computer and used as required.

A variety of special equipment is required for such systems in addition to the central computer and communications equipment. This equipment may include carrier repeaters, special capacitors at substations and devices to put the carrier signals onto and off the power line. In this case, electronic equipment that isolates the power (high voltage) from the relatively low level carrier signals serves to prevent power leakage problems and present the proper electrical interface conditions.

Installation of this type of system requires special testing procedures that are not required for other types of warning systems. These test procedures are required to select the proper carrier frequency, to determine existing electrical noise conditions, line impedances, and to determine the effects that various line transformers may have on the carrier and modulated signals. Such tests are required for each individual system installation to effectively custom fit the carrier frequency to each system. This is necessary since no two electrical power distribution systems are affected equally by the variety of conditions and interference levels found at each installation. Furthermore, the placement of blocking capacitors must be defined relative to their physical installation and their electrical position in each system. This requires a thorough study of the electrical schematics for the power distribution system.

Another major part of this type of system includes centralized computer control. A system of this type might be intended for several thousand users. Therefore, the capabilities of this communications system and the type and size of the computer and its peripheral units will become an important factor in final system design and complexity. Generally the computer system will have a CRT for operator control, a hard disc for data base collection and a line printer for report and message hard copy. Other communications devices can be added to provide data links to other computers. For example, when a system such as this has a dual purpose of warning as well as meter reading, etc., a communications link to a central billing computer would aid in automating this process.

At the meter itself, the warning device most easily implemented is an electrically driven horn that is activated and deactivated by the proper contact closer of the meter. The output power level of a horn used in this application is a nominal 100 db at six feet. This level would normally be sufficient to alert individuals inside a house as well as in the immediate area since the meter unit is attached to the house. A variety of other warning methods could be implemented; i.e., inside lights, horn, buzzer, etc. In either case, the method used for warning is merely dependent upon the cost/benefits of installation and the eventual maintenance costs of such a system. Here the utility may find that a warning device installed at the meter may be adequate for warning and would simplify the testing and maintenance of such units as compared to internally (in-house) installed warning devices.

NOTE

The DIDS system as described in Section 7.0 will be modified based upon data recently received on the Mobil Low Frequency Warning System.

7.0 DIDS DESCRIPTION

DIDS is defined as the Decision Information Distribution System. This system is explained in two reports: "National Warning System Analysis," May 15, 1974, and "Evaluation of Alternative Warning Configurations," April 30, 1976. The DIDS system as described in this Section will be modified based upon data recently received on the Mobil Low Frequency Warning System.

The DIDS system is a radio tone alert/voice type of warning and communications system funded by what was then (circa 1970's) Defense Civil Preparedness Agency (DCPA). Separate locations were planned for control of the system, and for location of the transmitters.

Operationally, a control center area in Olney, Maryland known as the National 3 Warning Center (N3WC) was established. Two modes of operation, termed automatic and semiautomatic or ad-lib, were defined. In the automatic mode, one of several recorded voice messages for printer devices (punched paper tape) could be transmitted to several or all receiver locations. Ad-lib allowed for voice messages not recorded to be transmitted.

Ten transmitter site locations for the system were planned, operating on 10 different frequencies in the frequency band from 163-197kHz. The first transmitter site in operation was located in Edgewood, Maryland with 50kw of output power. This gave a radio coverage area extending from Maryland in all directions, as shown in Figure 1.

The connection from the control center at N3WC (Olney, Maryland) to the transmitter at Edgewood, Maryland was by leased land telephone line. In case of problems in this area, a provision was made to use the military communications network, AUTOVON and also to allow for remote control of the transmitter by the National Weather Service Forecast Office (NWS) in Suitland, Maryland. In either case (N3WC or NWS), a coding system for the transmitted signal via the control

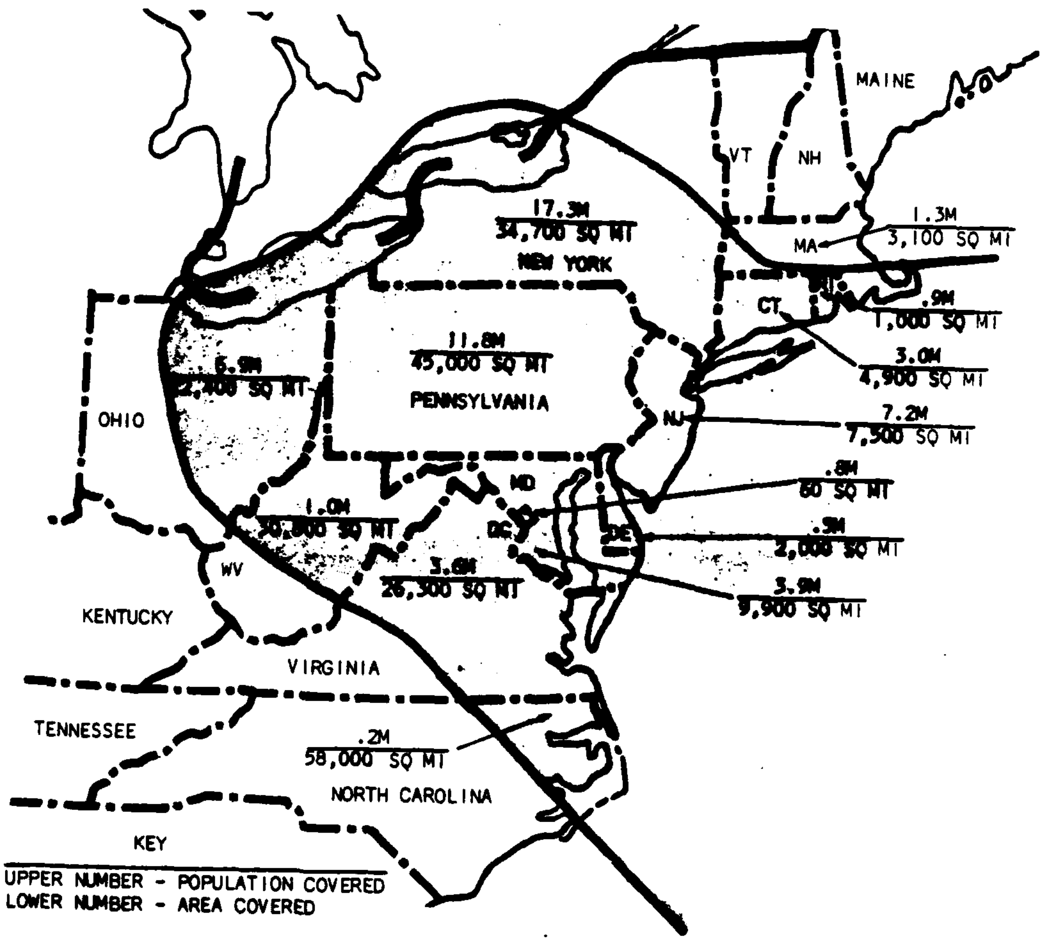
MAINE
VT
NH
17.3M
34,700 SQ MI
NEW YORK
MA
1.3M
3,100 SQ MI
CT
.9M
1,000 SQ MI
3.0M
4,900 SQ MI
11.8M
45,000 SQ MI
PENNSYLVANIA
OHIO
NJ
7.2M
7,500 SQ MI
.8M
60 SQ MI
MD
1.0M
DC
DE
.5M
2,000 SQ MI
WV
3.6M
26,300 SQ MI
3.9M
9,900 SQ MI
KENTUCKY
VIRGINIA
TENNESSEE
.2M
58,000 SQ MI
NORTH CAROLINA
KEY
UPPER NUMBER - POPULATION COVERED
LOWER NUMBER - AREA COVERED

FIGURE 1

center in Olney allowed for the capability of selective activation of radio receivers in the system. This selection was implemented by an address coding system for each receiver to respond to specific transmitted signals.

The receivers for the DIDS system were specially designed to operate as radio receivers for alerting individuals and for controlling the turn-on/turn-off of sirens or small siren systems.

In actual operation, a receiver intended for alerting an individual would operate in effect as if in a standby condition, i.e., the receiver, although powered on electricity did not output any sound or signal until its specific address was transmitted. Once the receiver address was transmitted, a voice or other type of message could be sent to all activated receivers. A turn-off signal was also transmitted to terminate a message. This type of turn-on/turn-off operation also applies to printer units and to receiver controllers of individual sirens. In the latter case, the receiver is only required to provide a relay contact closer as an output instead of a voice message.

In practice, receivers where voice output is given are intended for use during the various disaster conditions to alert key officials (governors, mayor, police, disaster service agencies, etc.), large institutions, wire services, and other key personnel and agencies.

DIDS receivers were not originally intended for direct warning of the general population, since this would require the special radios designed for the system. Distribution and manufacture of such radios, would require a large monetary expense that is greater than present agency funding capabilities. Other problems such as testing and maintenance of such an unprecedented program are not addressed in this report or any of the other referenced reports.

7.01 DIDS USAGE

Various disaster scenarios addressed here, for which DIDS might be used, include nuclear attack, natural disaster or nuclear power plant emergencies. For nuclear attacks, this system would seem well designed for rapid dissemination of warning to key personnel and institutions since the control is directly associated with various military communication networks. In fact the system is designed for this rapid type of response. For the natural disaster scenario, the DIDS systems may be effective where the initial disaster warning originated with the National Weather Service. In other natural disasters, the system response would probably be longer than desired, since the nature of the disaster cannot be determined and therefore the initial reporting person or agency is not likely to be reasonably familiar with the DIDS system.

In those areas where nuclear power plant problems occur, initially, the problem is very localized (i.e., 10 mile radius) and current regulations require the capability to be able to immediately warn local, state, and federal officials as well as the local population. As it currently exists, the DIDS system has the kind of capabilities required such as individual alerting, institutional alerting and selective control of such alert/warning capability. However, the control of the DIDS system for such purposes would have to be decided on an individual basis and possibly may serve as a back-up system for this condition, rather than a primary warning system.

8.0 NAWAS

NAWAS (National Warning System) is a major part of the National Civil Defense Warning System and allows for warning and emergency messages to be given to FEMA regional areas and to statewide areas. NAWAS is a dedicated telephone system leased from American Telephone and Telegraph (AT&T) and the Bell system, as well as private telephone companies. AT&T provided that portion which connects the various warning points with the other telephone companies. NAWAS is, effectively, a large party line type of telephone system with approximately 2,200 stations or terminations.

There are two national warning centers, one in Colorado and the other in Maryland. These centers control 10 regional centers distributed throughout the U.S. These regional centers, in turn, control state centers and local warning points. In addition, several NOAA weather stations have access to NAWAS.

When NAWAS is not being used for emergencies or tests, the state and local government locations may use the system for official business.

Operationally, the national, regional, and state centers and the on-line NOAA stations have the capability to alert local stations of an emergency. All NAWAS communications are oral, however, tone signals are also transmitted. These signals are used to activate various switching devices which then establish the circuit configuration.

Each state has its state warning point on a regional circuit. Most state warning points are manned on a 24-hour basis and located at state police headquarters, state highway patrol headquarters, or a similar facility that provides 24-hour coverage.

In a number of states, NAWAS is supplemented by networks of computer terminals. These networks are usually operated by the state police, highway patrol, or the department of justice. These networks often have their control points located in the same facilities as the state warning point. Upon receipt of a warning message from one of the National Warning Centers via NAWAS, the warning information is manually entered into the computer network and, once entered, is automatically relayed to all points on the network.

Warning information is disseminated from NAWAS warning points to state, county, and local governments; institutions such as schools and hospitals; large businesses and industries; and radio and television stations. The general public is warned by the news media (radio, television, or other).

The application of NAWAS for localized warning as applied to nuclear power plants is complicated by various factors. It would be difficult to adopt NAWAS for the warning of the local population within 15 minutes in a small area, as required the by NRC. Since NAWAS is a voice telephone system to various central points, the time required for these points to warn the general population would require another type of warning system to ensure that the message was received. For this reason, further details on NAWAS will be included only where NAWAS can easily be used as part of a smaller warning system.

9.0 ENCODER/DECODERS

Encoders and decoders can be considered as (1) encoder: a device that provides a code to another device, (2) decoder: a device which detects the code. The code has a meaning which is then used to activate a device. This then is effectively a command to take some action. This action can be that of activating a siren, a tone alert radio, ringing a telephone, turning on a light, etc. The types of encoder/decoders intended for discussion here are those electronic devices used in various warning and communications systems. These devices are usually solid state electronic devices. The encoder feeds its output (coded signal) to the transmitter which in turn transmits (either by radio or by wire) this coded signal. The receiver then takes this transmitted signal and processes (demodulates) it where the code is removed from the transmitted carrier. The code is then further processed by the decoder which can convert the code to a usefull output. There are a series of other steps involved in such processes such as signal conditioning, level conversion, interfaces to other devices, etc., but these need not be identified here.

Note that encoders/decoders can be termed as those devices that are necessary to make a system:

- Secure from being decoded or understood by nonusers
- Immune, or nearly so, from false activation

In the process of accomplishing the above, encoders and decoders become more complex. For example, the number of bits or tones in a code can almost be considered as proportional to the degree of security from decoding as well as from false activation. Furthermore, the greater number of bits per code determines the degree of probability for a duplicate code existing elsewhere. As the number of bits increases, the probability of another similar code decreases.

For example, consider that a simple combination lock is purchased, and there are *only two numbers* (from 0 to 9 for each digit) for the combination. This means that there are 99 different combinations possible (100 if 00 is used) for this lock. Considering then that if 1,000 locks are sold, then there are many duplicate combinations. (The lock is the encoder and the user the decoder.) This analogy can be applied to the encoder/decoder used with various warning systems. The transmitters for many warning systems operate on the police, fire, or local government frequencies. These frequencies are used throughout the United States, Canada, Mexico, etc. Certain frequencies (mostly low band) have a skip distance associated with their operation, especially at night, caused by various atmospheric conditions where it is not uncommon for a receiver in New York State to easily hear the transmitter signals in Arizona. Note that normal coverage for the transmitter is approximately 30-40 miles radius. Consider the use of a very simple encoder for activating a warning system in one of these areas. Then the possibility for false activation of one of these systems is increased greatly.

The examples of the transmitter and encoder/decoder types given in the two previous paragraphs are meant to illustrate the importance of proper selection of encoders and decoders for warning systems. These paragraphs simplify the problem. Other considerations are required in selecting an encoder/decoder system. These factors include:

- Transmitter interference/reliability
- System size
- Number of functions required (group, individual or various combinations of activation)
- User convenience
- Security requirements

Transmitter interference that can be expected is not easily predetermined when new frequency licenses are granted. As a result, the amount of interference is not always controllable. What is controllable is the method of encoding which has a direct affect on system reliability. When interference is possible, the code selection and encoder/decoder capabilities must be considered. Since system size determines the number of units that must be activated, the next determination that must be made is how many units must be capable of being activated individually and when activated, how many different functions must be performed. If each unit requires an individual address, and there are 30 units, then the address portion of the encoder must have 30 different combinations. In binary arithmetic, this translates to five bits or five different tones. Then assume each unit must be activated (turned on), perform these functions (e.g., a siren: fire, attack, and nuclear warning sounds), and be deactivated (turned off). This constitutes five functions or at least three additional binary bits or tone combinations. Note that the code is now eight bits long.

The actual manner of implementing such codes varies from one manufacturer to another. An example of the encoder/decoder scheme used by Whelen Engineering, a siren manufacturer, is given in Appendix C. This appendix is from a brochure on the Whelen 800 Series Warning Siren Activation and Control System and is also typical of those for other siren manufacturers.

LIST OF ABBREVIATIONS

ambient noise — All sounds present in an environment

ampere — Amps (abbr.); a unit of electrical current or rate of flow of electrons

automatic telephone dialer — Units capable of dialing many numbers in sequence and verifying answering, playing a recorded message, or redialing the number if it was busy or did not answer

bandwidth — The range within the limits of a band

beeper — Radio paging unit, a small receiver capable of emitting a sound alert

decibels — dB (abbr.); a logarithmic scale used in rating sound strength

dB(A) — An adjusted measurement of sound strength which gives more weight to frequencies to which the human ear is most sensitive

dBC — Rated sound output in decibels at 100 feet

DIDS — Decision Information Distribution System

directional — Wave radiation which is concentrated in a given direction

dual-tone — A tone having two pitches

EPZ — Emergency Planning Zone

FEMA — Federal Emergency Management Agency frequency — The number of times per second that an alternating current or an analog signal passes through a complete cycle

hertz — Hz (abbr.); a unit of frequency equal to one cycle per second

modulated power lines — A method of communication by modulation of the power line carrier; usually intended for purposes such as automatic electric power

MTBF — Mean Time Between Failures

NAWAS — National Warning System

NOAA — National Oceanic and Atmospheric Administration

NOAA radio — Up-to-date weather report service given by the National Weather Service branch of NOAA which is broadcast for pickup by special radio receivers

NRC — Nuclear Regulatory Commission

omni-directional — Not favoring any one direction

output power level — The measurement of the strength of sound waves emitted by a siren

pitch — That attribute of auditory sensation by which sounds may be ordered on a scale from low to high (e.g., the musical scale)

port — A place of access to a system or circuit

RF — radio frequency

RPM — Revolutions per minute

single-tone — A tone of only one pitch or frequency

siren — A hardware unit capable of emitting an attention getting sound over a large area; sirens are either electromechanical or electronic and can operate as either directional or omni-directional

solid-state — Pertaining to circuits and components made from semiconductor material, e.g., transistor, integrated circuit

tone — A sound wave capable of exciting an auditory sensation having pitch

tone alert radio — A type of radio receiver which can be radio-activated in order to broadcast warning/emergency messages

VAC — Voltage alternating current

VDC — Voltage direct current

Appendix A

APPENDIX A.

This appendix consists of a listing of technical specifications for each siren by their descending output power levels. They have been categorized by the four manufacturers. They include the following:

A.C.A. Alerting Communications of America

Hurricane
Allertor
Alertronic 4000
Alertronic 5000
Penetrator 10
Penetrator 50
Cyclone
Howler
Super Banshee
Banshee
Screamer S-10
Screamer S-7.5
Screamer S-5
Screamer S-2.5

Federal Signal Corporation

Thunderbolt 1000A, 1000B, 1000AT and 1000BT
SiraTone EOWS*812
SiraTone EOWS*612
Thunderbolt 1003A, 1003B
500A
SiraTone EOWS*408
STH10A, STH10B, STL10A and STL10B
3T22A/3T22B
SiraTone EOWS*115
5A/5B
2

Sentry Siren, Inc.

10V2T/10V2T-3S
10V
M10/M5
5V
3V8

Whelen Engineering

WS-2000-109
WS-2000-112
WS-2000-R
WS-2500
WS-3000

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: A.C.A. Alerting Communicators of America

Model Number: Pentrator 50 — P.50

Type: Electromechanical, Rotating-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
135 dBC	a. 230 VAC 3 Ø @ 95 amp running, 500 amp starting b. 460 VAC 3Ø @ 48 amp running, 250 amp starting c. 208VAC 3Ø @ 107 amp running, 550 amp starting	Alert: 460/690 Hz dual tone Attack: 460/690 Hz dual tone Fire: 460/69Hz dual tone	Weight 900 lbs, 8 feet long 6 feet wide 8 feet height

Description

The Penetrator 50 is the most powerful electromechanical rotating directional siren manufactured in the United States as of 1983. It uses a 50-HP 3-phase motor with a $3 \pm .5$ RPM rotation. The output beam is formed for 15° above and below horizontal and all exterior parts are fiberglass. It is a dual tone siren and can be locally or remotely controlled. Radio equipment is supplied by other manufaturers.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: A.C.A. Alerting Communicators of America

Model Number: Hurricane

Type: Electromechanical, Rotating-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
130 dBC	Compressor Assembly: a. 230 VAC 3Ø @ 78 Amps running and 480 Amps starting b. 460 VAC 3Ø @ 39 Amps running and 240 Amps starting Chopper: a. 230 VAC 1Ø @ 5.5 Amps running and 40 Amps starting Rotator: a. 230 VAC 1Ø @ 1 Amp running and 15 Amps starting	Alert: 465/582 Hz dual tone Attack: 465/582 Hz dual tone Fire: 465/582 Hz dual tone (other single or dual tones available)	Horn assembly: 82"L x 54" Dia. @ 250 lbs. Compressor: 38"W x 40"H x 40" Dia. @ 650 lbs.

Description

The Hurricane is a rotating-directional, electromechanical siren using a 30 HP motor for an air compressor to output 130 dBC. Mounting requires an air pipe from the compressor to the blower/horn assembly. Pole mounting is recommended, however, roof mounting is possible. Rotation is 360° at 2.5 RPM in a beam 3° above horizontal to 24° below horizontal. This siren is capable of single or dual-tone and can be locally or remotely controlled. A.C.A. units, when radio controlled, are equipped with radio receivers from other manufacturers. It is one of the most powerful sirens manufactured.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: A.C.A. Alerting Communicators of America

Model Number: Allertor

Type: Electromechanical, Rotating-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
127 dBC	a. 230 VAC 1Ø @ 60 Amps running b. 230 VAC 3Ø @ 31.5 Amps running c. 460 VAC 3Ø @ 16 Amps running	Alert: 523/698 Hz dual tone Attack: 523/698Hz dual tone Fire: 523/698 Hz dual tone	7'L x 3'W x 5'H @ 450 lbs.

Description

The Allertor is an electromechanical, rotating-directional, dual-tone siren using a direct-drive 10 HP motor to output 127 dBC. This unit is capable of being remotely activated and is of a size that allows for Class II pole mounting. Rotation is 360^{o} at 3.5 RPM in a beam 10^{o} above horizontal to 15^{o} below horizontal. A.C.A. units, when radio controlled, are equipped with radio receivers from other manufacturers.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: A.C.A. Alerting Communicators of America

Model Number: Penetrator 10

Type: Electromechanical, Rotating directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
125 dBC	a. 230 VAC 1ø @ 60 Amps running b. 230 VAC 3ø @ 31.5 Amps running c. 460 VAC 3ø @ 16 Amps running	Alert: 523/698 Hz dual tone Attack: 523/698Hz dual tone Fire: 523/698 Hz dual tone	38"L x 47"W @ 376 lbs.

Description

The Penetrator 10 is an electromechanical, rotating-directional, dual-tone siren using a direct-drive 10 HP motor to output 125 dBC. This unit is capable of being remotely activated and is of a size that allows for Class II pole mounting. Rotation is 360° at 3.5 RPM in a beam 15° above horizontal to 15° below horizontal. A.C.A. units, when radio controlled, are equipped with radio receivers from other manufacturers.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: A.C.A. Alerting Communicators of America

Model Number: Cyclone

Type: Electromechanical, Omni-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
125 dBC	230 VAC 3Ø @ 116 Amps running and 850 Amps starting	Alert: 465/698 Hz dual tone Attack: 465/698 Hz dual tone Fire (optional): 465/698 Hz dual tone	Standard model: 31.5" H x 60" Dia. @ 682 lbs. Multi-signal model: 51"H x 60" Dia. @738 lbs.

Description

The Cyclone is an electromechanical, omni-directional, dual-tone siren using a direct-drive 50 HP motor to output 125 dBC. It can be easily pole mounted and directly or remotely controlled. Note that a significant amount of power is required for operation as compared to directional sirens with the same output power level. A.C.A. units, when radio controlled, are equipped with radio receivers from other manufacturers.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: A.C.A. Alerting Communicators of America

Model Number: Alertronic 5000

Type: Electronic, Rotating-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
125 dBC Siren Not available, Voice	a. 115 VAC for battery battery operation is from internal batteries	Alert, Attack, Fire, and voice output. Single Tone 500 Hz or Dual tone, 500/680 Hz adjustable	Weight 580 lbs 72" high 60" wide 49" deep

Description

The Alertronic 5000 is an electronic rotating directional siren and public address unit with a siren output of 125dBC. It is battery powered. The system allows for approximately 30 continuous minutes of operation before battery recharge is required.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: A.C.A. Alerting Communicators of America

Model Number: Howler

Type: Electromechanical, Rotating-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
123 dBC	a. 230 VAC 1ø @ 60 Amps running b. 230 VAC 3ø @ 31.5 Amps running c. 460 VAC 3ø @ 16 Amps running	Alert: 523/698 Hz dual tone Attack: 523/698 Hz dual tone Fire: 523/698 Hz dual tone	36"L x 36"W x 40"H @ 400 lbs.

Description

The Howler is an electromechanical, rotating-directional, dual-tone siren using a direct-drive 10 HP motor to output 123 dBC. This unit can be locally or remotely activated and is of a size that allows for Class II pole mounting. Rotation is 360^{o} at 3.5 RPM. A.C.A units, when radio controlled, are equipped with radio receivers from other manufacturers.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: A.C.A. Alerting Communicators of America

Model Number: Banshee

Type: Electromechanical, Omni-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
116 dBC single tone 112 dBC dual tone	a. 230 VAC 1ϕ @ 48 Amps running and 240 Amps starting b. 230 VAC 3ϕ @ 30 Amps running and 175 amps starting c. 208 VAC 3ϕ @ 34 Amps running and 195 Amps starting	Alert: 460 Hz single tone 517/690 Hz dual tone Attack: 460 Hz single tone 517/690 Hz dual tone Fire: 517/690Hz dual tone	30"H x 42"Dia. @ 430 lbs.

Description

The Banshee is an electromechanical, omni-directional siren using a direct-drive 10 HP motor. The single-tone siren has an output power of 116 dBC and the dual-tone siren has an output power of 112 dBC. It can be easily pole or roof mounted and can be locally or remotely controlled. Sound output is beamed 360°, 0° horizontal to 20° below horizontal. A.C.A. units, when radio controlled, are equipped with radio receivers from other manufacturers.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: A.C.A. Alerting Communicators of America

Model Number: Alertronic 4000

Type: Electronic, Omni-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
115 dBC Siren Not available, Voice	a. 115 VAC for battery battery, operation is from internal batteries	Alert, Attack, Fire, and voice output. Single Tone 500 Hz or Dual tone, 500/680 Hz adjustable	Not available

Description

The Alertronic 4000 is an electronic omni-directional siren and public address unit with a siren output of 115dBC. It is battery powered. The system allows for approximately 30 continuous minutes of operation before battery recharge is required.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: A.C.A. Alerting Communicators of America

Model Number: Screamer S-10

Type: Electromechanical, Omni-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
112 dBC	a. 230 VAC 1ϕ @ 45 Amps running and 200 Amps starting b. 230 VAC 3ϕ @ 27 Amps running and 150 Amps starting	Alert: 460/517/690 Hz* dual tone Attack: 460/517/690 Hz* dual tone Fire: 460/517/690 Hz* dual tone	34"H x 42"Dia. @ 427 lbs.

Description

The Screamer S-10 is an electromechanical, omni-directional, dual-tone, 112 dBC siren powered by a direct-drive 10 HP motor. *It can be controlled directly or remotely and can be easily pole mounted. Sound is dispersed* 360° continuously in a beam 0° horizontal to 20° below horizontal. A.C.A. units, when radio controlled, are equipped with radio receivers from other manufacturers.

*Depending upon options ordered.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: A.C.A. Alerting Communicators of America

Model Number: Screamer S-7.5

Type: Electromechanical Omni-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
108 dBC	a. 230 VAC 1∅ @ 33 Amps running and 150 Amps starting b. 230 VAC 3∅ @ 20 Amps running and 100 Amps starting	Alert: around 517 Hz dual tone Attack: around 517 Hz dual tone Fire: around 517 Hz dual tone	28"H x 31"Dia. @ 260 lbs.

Description

The Screamer S-5.7 is an electromechanical, omni-directional, dual-tone, 108 dBC siren powered by a direct-drive 7.5 HP motor. It can be controlled directly or remotely and can be easily pole mounted. Sound is dispersed 360° continuously in a beam 0° horizontal to 20° below horizontal. A.C.A. units, when radio controlled, are equipped with radio receivers from other manufacturers.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: A.C.A. Alerting Communicators of America

Model Number: Screamer S-5

Type: Electromechanical, Omni-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
105 dBC	a. 230 VAC 1ø @ 21 Amps running and 100 Amps starting b. 230 VAC 3ø @ 12.4 Amps running and 65 Amps starting	Alert: around 517 Hz dual tone Attack: around 517 Hz dual tone Fire: around 517 Hz dual tone	24"H x 31"Dia. @174 lbs.

Description

The Screamer S-5 is an electromechanical, omni-directional, dual-tone, 105 dBC siren powered by a direct-drive 5 HP motor. It can be controlled directly or remotely and can be easily pole mounted. Sound is dispersed 360° continuously in a beam 0° horizontal to 20° below horizontal. A.C.A. units, when radio controlled, are equipped with radio receivers from other manufacturers.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: A.C.A. Alerting Communicators of America

Model Number: Screamer S-2.5

Type: Electromechanical, Omni-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
101 dBC	a. 230 VAC 1Ø @ 11.5 Amps running and 50 Amps starting b. 230 VAC 3Ø @ 10.2 Amps running and 50 Amps starting c. 115 VAC 1Ø @ 22 Amps running and 100 Amps starting	Alert: around 517 Hz dual tone Attack: around 517 Hz dual tone Fire: around 517 Hz dual tone	22" Dia. x 21"H @ 100 lbs.

Description

The Screamer S-2.5 is an electromechanical, omni-directional, dual-tone, 101 dBC siren powered by a direct-drive 2.5 HP motor. It can be controlled directly or remotely and can be easily pole mounted. Sound is dispersed 360° continuously in a beam 0° horizontal to 18° below horizontal. A.C.A. units, when radio controlled, are equipped with radio receivers from other manufacturers.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: Federal Signal Corporation

Model Number: Thunderbolt 1000A, 1000B, 1000AT and 1000BT

Type: Electromechanical, Rotating-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
127 dBC - 1000A/1000B 125 dBC - 1000AT/1000BT	1000A/1000AT: a. 240 VAC 3Ø @ 33 Amps running and 230 Amps starting b. 480 VAC 3Ø @ 20 Amps running and 150 Amps starting 1000B/1000BT: a. 240 VAC 1Ø @ 50 Amps running and 295 Amps starting	1000A and 1000B: Alert: 550 Hz single tone Attack: 550 Hz single tone 1000AT and 1000BT: Alert: 550/660 Hz dual tone Attack: 550/660 Hz dual tone	Horn assembly: 54"L x 28"W x 28"H @ 86 lbs. Chopper assembly: 9 3/4 Dia. @ 37 lbs. Rotator assembly: 22"L x 15"W x 36"H @ 185 lbs. Blower assembly: 56"L x 33"W x 30"H @ 585 lbs.

Description

The Thunderbolt Models 1000 are rotating-directional, electromechanical sirens using compressed air forced through a stand pipe to a rotator and chopper assembly. The horn, chopper, and rotator assembly can be pole or roof mounted. A 3" diameter stand pipe conveys the air from the 585 pound compressor assembly below to the rotator and chopper assembly above. A horn assembly rotates 360^{o} at either 2, 4, or 8 RPM depending upon desired speed. Model numbers with A signify 3-phase operation; B signifies single-phase; T signifies dual-tone, otherwise single-tone operation. The dual-tone siren has an output of 125 dBC and the single-tone siren has an output of 127 dBC. This siren can be locally or remotely controlled.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: Federal Signal Corporation

Model Number: SiraTone EOWS*812

Type: Electronic, Rotating-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
126 dBC single tone 124 dBC dual tone	a. 24VDC (2-12VDC batteries in series) b. 115VAC @ 8 Amps or 240VAC @ 4 Amps for battery charger	Alert, Attack, and Fire 300/1050 Hz range	Cabinet: 20"W x 26"H x 12"Dia. @ 128 lbs. Spealson cluster: 33" long x 52" wide x 108" high at 840 lbs.

Description

The SiraTone EOWS*812 is an electronic, rotating-directional siren and public address unit powered by 2-12VDC batteries with a single-tone output of 126 dBC, dual-tone output of 123 dBC or less, and a voice output of 120 dBC. The 8-speaker cluster is suitable for pole mounting and can be locally or remotely controlled. Rotational speed 0.75 to 1.50 RPM.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: Federal Signal Corporation

Model Number: Thunderbolt 1003A, 1003B

Type: Electromechanical, Rotating-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
125 dBC	1003A: a. 240 VAC 3ϕ @ 33 Amps running and 230 Amps starting b. 480 VAC 3ϕ @ 20 Amps running and 150 Amps starting 1003B: a. 240 VAC 1ϕ @ 50 Amps running and 295 Amps starting	Alert: 550/660 Hz dual tone Attack: 550/660 Hz dual tone Fire: 550/660 Hz dual tone (Other signals available as an option)	Horn assembly: 54"L x 28"W x 28"H @ 86 lbs. Chopper assembly: 9 3/4 Dia. @ 37 lbs. Rotator assembly: 22"L x 15"W x 36"H @ 185 lbs. Blower assembly: 56"L x 33"W x 30"H @ 585 lbs. Solenoid housing: 24"L x 5"W x 4"H @ 25 lbs.

Description

The Thunderbolt Models 1003 are electromechanical, rotating directional, dual tone sirens using compressed air to output 125 dBC. The horn, chopper, and rotator assembly can be pole mounted. A 3" diameter stand pipe conveys the air from the 585 pound compressor assembly below to the rotator and chopper assembly above. The horn assembly rotates 360° at either 2, 4, or 8 RPM depending upon desired speed. Model A signifies 3-phase operation; B signifies single-phase operation. This siren can be locally or remotely controlled.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: Federal Signal Corporation

Model Number: SiraTone EOWS*612

Type: Electromechanical, Rotating-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
124 dBC @ 850 Hz range (siren) less at lower frequencies	a. 24 VDC (two 12 VDC batteries connected in series) b. 115 VAC @ 80 amps or 240 VAC @ 4 amps for battery charger.	Alert, Attack, Fire and others at 300/1050 Hz range	Speaker Cluster: 33" long, 52" wide, 84" high at 370 lbs.

Description

The SiraTone EOWS*612 is an electronic, rotating-directional siren and public address unit powered by two 12-VDC batteries with single or dual tone output. Output power at 850 Hz is 124 dBC and less and lower frequencies. The six speaker unit is suitable for pole mounting and can be locally or remotely controlled. Rotational speed is 0.75 to 1.50 RPM.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: Federal Signal Corporation

Model Number: 500A (Not currently manufactured)

Type: Electromechanical, Rotating-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
123 dBC	a. 208-240 VAC 3Ø @ 34 Amps running and ___ Amps starting b. 480 VAC 3Ø @ 17 Amps running and _____ Amps starting		53"H x 70"Dia. @ 605 lbs.

Description

The 500A is an electromechanical, rotating-directional siren using a direct-drive motor to output 123 dBC. This siren was designed to be base mounted. Pole mounting requires special mounting hardware not supplied by the manufacturer. Note that this siren is not currently manufactured.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: Federal Signal Corporation

Model Number: SiraTone EOWS*408

Type: Electronic, Rotating-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
122 dBC single tone 118 dBC dual tone 116 dBC voice	a. 24VDC (2-12VDC batteries connected in series b. 115VAC @ 8 Amps or 240 VAC at 4 Amps for battery charger	Alert, Attack, and Fire: 300/1050 Hz range Typically set at 850 or 1020 Hz	Cabinet: 20"W x 26"H x 12"Dia @ 128 lbs. Battery enclosure: 18"W x 18"H x 20"D, @ 112 lbs. *Speaker cluster:* 33" long x 52" wide 58" high @ 560 lbs.

Description

The SiraTone EOWS*408 is an electronic, rotating-directional siren and public address unit powered by 2-12VDC batteries with a single-tone output of 122 dBC, dual-tone output of 118 dBC and voice output of 116 dBC or less. The 4-speaker unit is suitable for pole mounting and can be locally or remotely controlled. Rotational speed 0.75 to 1.50 RPM.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: Federal Signal Corporation

Model Number: STH10A, STH10B, STL10A and STL10B

Type: Electromechanical, Omni-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
115 dBC	STH10A/STL10A: a. 208-240 VAC 3Ø @ 34 Amps running and 150 Amps starting b. 480 VAC 3Ø @ 17 Amps running and 75 Amps starting STH10B/STL10B: a. 240 VAC 1Ø @ 50 Amps running and 125 Amps starting	STH10A/STH10B: Alert: 675 Hz single tone Attack: 675 Hz single tone STL10A/STL10B: Alert: 387 Hz single tone Attack: 387 Hz single tone	STH10A/STL10A: 51" Dia. x 79"H @ 450 lbs. STH10B/STL10B: 51" Dia. x 89"H @ 470 lbs.

Description

The Model STH10A or B and STL10A or B are electromechanical, omni-directional, 115 dBC sirens using a direct-drive 7.5 HP motor for 3-phase operation, or a 10 HP motor for single-phase operation. The STH series has a higher output frequency than the STL series. Model A signifies 3-phase operation; B signifies single-phase operation. This siren can be locally or remotely controlled.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: Federal Signal Corporation

Model Number: 3T22A/3T22B

Type: Electromechanical, Omni-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
115 dBC	3T22A: a. 208-240 VAC 3ϕ @ 28 Amps running and 150 Amps starting b. 480 VAC 3ϕ @ 11 Amps running and 75 Amps starting 3T22B: a. 240 VAC 1ϕ @ 50 Amps running and 125 Amps starting	Alert: 550/660 Hz dual tone Attack: 550/660 Hz dual tone Fire: 550/660 Hz dual tone	3T22A: 100"H x 52" Dia. @ 655 lbs. 3T22B: 105"H x 52" Dia. @ 725 lbs.

Description

The 3T22 is an omni-directional, electromechanical, dual tone, 115 dBC siren using a direct-drive 7.5 HP motor for 3-phase operation or 10 HP motor for single-phase operation. Two rings of directional cones, with 6 cones on the top and 12 cones on the bottom, form the siren, which can be pole mounted. The siren provides a dual-tone output and can be locally or remotely controlled. Model A signifies 3-phase operation; B signifies single-phase operation.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: Federal Signal Corporation

Model Number: SiraTone EOWS*115

Type: Electronic, Omni-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
113 dBC siren	a. 24VDC (2-12VDC batteries in series) b. 115VAC @ 8 Amps or 240VAC @ 4 Amps for battery charger	Alert, Attack, and Fire: 300/1050 Hz range	Cabinet: 20"W x 26"H x 12"Dia. @ 128 lbs. Battery enclosure: 18"W x 18"H x 20"Dia. @ 112 lbs. Speaker cluster: 55"H x 54"Dia. @ 360 lbs.

Description

The SiraTone EOWS*115 is an electronic, omni-directional siren powered by 2-12VDC batteries with dual-tone output of 113 dBC and voice output of 109 dBC or less. Battery operation is approximately 30 minutes before recharging is required. The 12-speaker cluster is suitable for pole mounting and can be locally or remotely controlled.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: Federal Signal Corporation

Model Number: 5A/5B

Type: Electromechanical, Omni-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
107 dBC	5A: a. 208-240 VAC 3ϕ @ 32 Amps running and 145 Amps starting b. 480 VAC 3ϕ @ 16 Amps running and 75 Amps starting 5B: a. 240 VAC 1ϕ @ 54 Amps running and 130 Amps starting	5A: Alert: 675 Hz single tone Attack: 675 Hz single tone 5B: Alert: 387 Hz single tone Attack: 387 Hz single tone	5A: 41" Dia. x 54"H @ 405 lbs. 5B: 41" Dia. x 54"H @ 425 lbs.

Description

The 5A and 5B are electromechanical, omni-directional sirens using a direct-drive __ Hp motor to output 107 dBC. Model A signifies 3-phase operation; B signifies single-phase operation. It is a single-tone siren and can be locally or remotely controlled.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: Federal Signal Corporation

Model Number: 2

Type: Electromechanical, Omni-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
102 dBC	a. 120 VAC 1ϕ @ 24 Amps running and 80 Amps starting b. 240 VAC 1ϕ @ 12 Amps running and 44 Amps	Alert: 487 Hz single tone 425/525 Hz dual tone Attack: 487 Hz single tone 424/525 Hz dual tone	31"H x 21" Dia. @ 60 lbs.

Description

The Model 2 is an electromechanical, omni-directional siren using a direct-drive 2 HP motor to output 102 dBC. This siren is probably the only siren in this output power range that can operate from 120 VAC, single-phase power.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: Sentry Siren, Inc.

Model Number: 10V2T/10V2T-3S

Type: Electromechanical, Omni-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
123 dBC	a. 230 VAC 1ϕ @ 45 Amps running and 160 Amps starting b. 230 VAC 3ϕ at 25 Amps running and 152 Amps starting c. 460 VAC 3ϕ @ 15 Amps running and 77 Amps starting	10V2T/10V2T-3S: Alert: 460/920 Hz dual tone Attack: 460/920 Hz dual tone 10V2T-3S: Fire: 460/920 Hz dual tone	56"H x 76" Dia. @ 450 lbs.

Description

The 10V2T siren is an electomechanical, omni-directional, dual-tone, 123 dBC siren using a direct-drive 10 HP motor for 3-phase and single-phase operation. This siren can be pole mounted on a Class II wooden pole and it can be locally or remotely controlled. Note that this siren is one of the few omni-directional sirens with an output power level near that of directional sirens. Model 10V2T provides the dual-tone alert and attack signals while the 10V2T-3S includes these signals as well as the fire signal.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: Sentry Siren, Inc.

Model Number: 10V

Type: Electromechanical, Omni-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
115 dBC	a. 230 VAC 1Ø @ 23 Amps running and 156 Amps starting b. 230 VAC 3Ø @ 19.4 Amps running and 116 Amps starting c. 460 VAC 3Ø @ 10 Amps running and 60 Amps starting (estimated)	Alert: 460 Hz single tone 460/920 Hz dual tone Attack: 460 Hz single tone 460/920 Hz dual tone Fire: 460 Hz single tone 460/910 Hz dual tone	41"H x 46" Dia. @ 305 lbs.

Description

The Model 10V siren is an electromechanical, omni-directional, 115 dBC siren with a direct-drive 7.5 HP motor for 3-phase operation or a 5 HP motor for single-phase operation. The standard model has eight output directional horns for 360° coverage at 460 Hz. A second set of directional horns can be added making this a dual-tone siren at 460/920 Hz. It can be mounted on a Class II wooden pole and can be locally or remotely controlled.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: Sentry Siren, Inc.

Model Number: M10/M5

Type: Electromechanical - Clover leaf pattern coverage

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
115 dBC - M10 112 dBC - M5	a. 230 VAC 1Ø @ 32 Amps running b. 230 VAC 3Ø @ 12.8 Amps running c. 460 VAC 3Ø @ 6.4 Amps running		M5: 52"L x 28"W x 25"H @ 280 lbs. M10: 58"L x 28"W x 25"H @ 305 lbs.

Description

The M10 and M5 are electromechanical sirens designed as cylinders which output a clover leaf pattern of sound, i.e., the sound is output on the ends. The M10 has an output of 115 dBC and the M5 an output of 112 dBC. These sirens can be pole mounted and can be locally or remotely controlled. This particular model is one of the oldest siren designs and has not been manufactured since 1978. A number of newer siren designs with 360° coverage have made this unit almost obsolete.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: Sentry Siren, Inc.

Model Number: 5V

Type: Electromechanical, Omni-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
112 dBC	a. 230 VAC 1∅ @ 26 Amps running, and 156 Amps starting b. 230 VAC 3∅ @ 19.4 Amps running, and 116 Amps starting c. 460 VAC 3∅ @ 10 Amps running, and 60 Amps starting	460 Hz or 920 Hz single tone	41"H x 46" Dia. @ 305 lbs.

Description

The 5V is an electromechanical, omni-directional, single-tone siren outputing 112 dBC with a direct-drive 7.5 HP motor for 3-phase operation or single-phase operation using a 5 HP motor. The standard model outputs a "low pitch" tone at 460 Hz or can be ordered with a "high pitch" tone at 920 Hz but does not output dual tone signals. It can be locally or remotely activated and mounted on a Class II wooden pole.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: Sentry Siren, Inc.

Model Number: 3V8

Type: Electromechanical, Omni-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
107 dBC	a. 230 VAC 1ø @ 17 Amps running and 103 Amps starting b. 115 VAC 1ø also available c. 230 VAC 3ø @ 9.6 Amps running d. 460 VAC 3ø @ 4.8 Amps running	460 Hz or 920 Hz single tone	36"H x 35" Dia. @ 230 lbs.

Description

The Model 3V8 is an electromechanical, omni-directional, single-tone siren using a direct-drive 3 HP motor to output 107 dBC. The unit can be pole mounted on a Class II wooden pole and can be locally or remotely controlled.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: Whelen Engineering

Model Number: WS-3000

Type: Electronic, Rotating-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
124 dBC at 800 Hz siren 122 dBC at 500 Hz siren	a. 115 VAC for battery charger. Two 12 VDC internal batteries con-neected for 24 VDC operation. b. Solar-powered charger available.	Wail, Attack, Alert, Fire, Air Horn, High and Low at 500 or 800 Hz Public address at 300 to 10,000 Hz.	Speaker assembly 53" deep, 68" high @ 310 lbs. Aluminum cabinet, 41" high, 30" wide, 10" deep @ 274 lbs.

Description

The WS-3000 is an electronic, rotating-directional siren and public address unit with a siren output of 124 dBC and a voice output of 120 dBC. It is powered by 2-12VDC batteries connected in series. The system allows for approximately 30 continuous minutes of operation before recharge is required. At least 3 to 4 hours is required for full battery recharge after extended use. A single phase 115 VAC line at 15 to 20 ampere rating is required for continuous battery charge and operation. Speaker rotation is in one direction for 360 degrees coverage and then back again for normal operation. One rotation in either direction takes approximately 15 seconds. The capability exists to point the speakers in 45° increments when used in the public address mode. Complete local or remote control is available for activation. Installation is generally on a Class II wooden pole with the speaker cluster near the top and the cabinet near the bottom.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: Whelen Engineering

Model Number: WS-2500

Type: Electronic, Omni-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
115 dBC at 800 Hz, siren 112 dBC at 500 Hz, siren	a. 115 VAC for battery charger. Two 12 VDC batteries connected for 24 VDC opertion. b. Solar-powered charger available.	Wail, Attack, Alert, Fire, Air Horn, high and low at 500 or 800 Hz. Public address at 300 to 10,000 Hz.	Speaker cluster, 42" diameter, 46" high @ 325 lbs. Aluminum cabinet: 41' high, 30" wide, 10" deep @274 lbs.

Description

The WS-2500 is an electronic omni-directional siren and public address unit with a 115 dBC siren output. It is powered by two 12 VDC batteries and can operate continuously for 30 minutes before recharging is required. The speakers are described as a "multicellular horn" as comared to multiple horn clusters. It can be mounted on a Class II wooden pole.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: Whelen Engineering

Model Number: WS-2000R

Type: Electronic, Rotating-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
115 dBC at 800 Hz, siren 112 dBC at 500 Hz, siren	a. 115 VAC for battery charger. Two 12 VDC internal batteries connected for 24 VDC operation. b. Solar-powered charger available.	Wail, Attack, Alert, Fire, Air Horn, high and low at 500 or 800 Hz. Public address at 300 to 10,000 Hz.	Speaker cluster, 21" deep, 58" high, 22" wide Aluminum cabinet: 41" high, 30" wide, 10" deep @274 lbs

Description

The WS-2000R is an *electronic rotating-directional* siren and public address unit with a 115 dBC siren output. It is powered by two 12 VDC batteries with a maximum 30 minutes of operation before recharge is required. Four vertical speakers are rotated by a motor in a weather proof assembly for 360° rotation. The speakers can be pointed stationary at 45° increments for the public address mode and remotely controlled for this operation, as well as other operational modes. Installation can be made on Class II wooden poles. This unit can also be mounted on a mobile trailer towed by a vehicle. The trailer has its own power source and telescoping speaker cluster.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: Whelen Engineering

Model Number: WS-2000-112

Type: Electronic, Omni-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
112 dBC at 800 Hz, siren 109 dBC at 500 Hz, siren	a. 115 VAC for battery charger. Two 12 VDC internal batteries connected for 24 VDC operation. b. Solar-powered charger available.	Wail, Attack, Alert, Fire, Air Horn, high and low at 500 or 800 Hz. Public address at 300 to 10,000 Hz.	Speaker cluster, 71" long, 36" high @ 313 lbs Aluminum cabinet: 41" high, 30" wide, 10" deep @274 lbs

Description

The WS-2000-109 is an electronic omni-directional siren and public address unit with a 112 dBC siren output. It is powered by two 12 VDC batteries and can operate continuously for 30 minutes before recharging is required. There are four 3-speaker clusters for the siren which can be mounted on a Class II wooden pole. This unit can also be mounted on a mobile trailer towed by a vehicle. The trailer has its own power source and telescoping speaker cluster.

SIREN MANUFACTURER'S DATA SHEET

Manufacturer: Whelen Engineering

Model Number: WS-2000-109

Type: Electronic, Omni-directional

Manufacturer's Published Output Power	Input Power Requirements	Output Signals/Frequencies	Physical Parameters
109 dBC at 800 Hz, siren 109 dBC at 500 Hz, siren	a. 115 VAC for battery charger. Two 12 VDC internal batteries connected for 24 VDC operation. b. Solar-powered charger available.	Wail, Attack, Alert, Fire, Air Horn, high and low at 500 or 800 Hz. Public address at 300 to 10,000 Hz.	Speaker cluster, 71" diameter, 24" high @ 225 lbs Aluminum cabinet: 41" high, 30" wide, 10" deep @274 lbs

Description

The WS-2000-109 is an electronic omni-directional siren and public address unit with a 109 dBC siren output. It is powered by two 12 VDC batteries and can operate continuously for 30 minutes before recharging is required. There are four 2-speaker clusters for the siren which can be mounted on a Class II wooden pole. This unit can also be mounted on a mobile trailer towed by a vehicle. The trailer has its own power source and telescoping speaker cluster.

Appendix B

APPENDIX B. NOAA WEATHER RADIO STATIONS

Location	Call Sign	Frequency MHz	Power Watts
ALABAMA			
Anniston	KIH-58	162.475	100
Birmingham	KIH-54	162.550	1000
Demoplis	WXL-72	162.475	1000
Dozier	KIH-59	162.550	800
Farley	WXM-66	162.425	100
Florence	KIH-57	162.475	800
Huntsville	KIH-20	162.400	250
Louisville	KIH-56	162.475	450
Mobile	KEC-62	162.550	330
Montgomery	KIH-55	162.400	1000
Tuscaloosa	KIH-60	162.400	1000
ALASKA			
Anchorage	KEC-43	162.550	100
Cordova	WXJ-79	162.550	500
Fairbanks	WXJ-81	162.550	500
Homer	WXJ-24	162.400	750
Juneau	WXJ-25	162.550	400
Ketchikan	WXJ-26	162.550	1000
Kodiak	WXJ-78	162.550	800
Nome	WXJ-62	162.550	1000
Petersburg	WXJ-82	162.550	1000
Seward	KEC-81	162.550	90
Sitka	WXJ-80	162.550	500
Valdez	WXJ-63	162.550	350
Wrangell	WXJ-83	162.400	500
Yakutat	WXK-69	162.550	250

Location	Call Sign	Frequency MHz	Power Watts
ARKANSAS			
Fayetteville	WXJ-52	162.475	100
Ft. Smith	WXJ-50	162.400	1000
Gurdon	WXJ-48	162.475	1000
Jonesboro	WXJ-51	162.550	500
Little Rock	WXJ-55	162.550	300
Mountain View	WXL-66	162.400	250
Star City	WXJ-54	162.400	500
Texarkana	WXJ-49	162.550	500
ARIZONA			
Flagstaff	WXK-76	162.400	100
Phoenix	KEC-94	162.550	330
Tucson	WXL-30	162.400	100
Yuma	WXL-87	162.550	100
CALIFORNIA			
Bakersfield	WXL-89	162.550	100
Barstow (not installed)			
Coachella	KIG-78	162.400	100
Crescent City/ Brkngs	KIH-37	162.550	1000
Eureka	KEC-82	162.400	330
Fresno	KIH-62	162.400	100
Los Angeles	KWO-37	162.550	500
Merced	WXL-99	162.550	1000
Monterey	KEC-49	162.400	330

Location	Call Sign	Frequency MHz	Power Watts
CALIFORNIA, (Continued)			
Point Arena	KIH-30	162.400	1000
Redding	WXL-88	162.550	100
Sacramento	KEC-57	162.400	330
San Diego	KEC-62	162.400	330
San Francisco	KHB-49	162.550	500
San Luis Obispo	KIH-31	162.550	330
Santa Barbara	KIH-34	162.400	330
COLORADO			
Alamosa	WXM-54	162.475	100
Colorado Springs	WXM-56	162.475	100
Denver	KEC-76	162.550	330
Grand Junction	WXM-55	162.550	300
Greeley	WXM-50	162.400	100
Longmont	WXM-51	162.550	100
Pueblo	WXM-52	162.400	100
Sterling	WXM-53	162.400	300
CONNECTICUT			
Hartford	WXJ-41	162.475	500
Meriden	WXJ-42	162.400	500
New London	KHB-47	162.550	330
DELEWARE			
Lewes	WXJ-94	162.550	500
DISTRICT OF COLUMBIA	KHB-36	162.550	1000
FLORIDA			
Clewiston	WXM-58	162.400	300
Daytona Beach	KIH-26	162.400	1000
Fort Myers	WXK-83	162.475	1000
Gainsville	WXJ-60	162.475	1000
Jacksonville	KHB-39	162.550	1000
Key West	WXJ-95	162.400	1000
Melbourne	WXJ-70	162.550	1000
Miami (will change)	KHB-34	162.550	1000
Orlando	KIH-63	162.475	500
Panama City	KGG-67	162.550	1000
Pensacola	KEC-86	162.400	500
Tallahassee	KIH-24	162.400	1000
Tampa	KHB-32	162.550	1000
West Palm Beach	KEC-50	162.475	500
GEORGIA			
Athens	WXK-56	162.400	600
Atlanta	KEC-80	162.550	500
Augusta	WXK-54	162.550	500
Baxley	WXM-65	162.525	300
Chatsworth	WXK-52	162.400	200
Columbus	WXK-55	162.400	100
Macon	WXK-71	162.475	1000
Pelham	WXK-53	162.550	500
Savannah	KEC-85	162.400	1000
Waycross	WXK-75	162.475	500
HAWAII			
Hilo	KBA-99	162.550	1000

Appendix B. Continued

Location	Call Sign	Frequency MHz	Power Watts
HAWAII, (Continued)			
Honolulu	KBA-99	162.550	250
Kokee	KBA-99	162.400	90
Mt. Haleakala	KBA-99	162.400	330
Waimanalo	TRNSL	162.400	10
IDAHO			
Boise	WXK-68	162.550	100
Lewiston	WXK-98	162.550	100
Pocatello	WXL-33	162.550	100
Twin Falls	WXL-35	162.400	100
ILLINOIS			
Champaign	WXJ-76	162.550	500
Chicago	KWO-39	162.550	500
Marion	WXM-49	162.425*	1000
Moline**	WXJ-73	162.550	1000
Peoria	WXJ-71	162.475	1000
Rockford	WXJ-74	162.475	1000
Springfield	WXJ-75	162.400	1000
INDIANA			
Evansville	KIG-76	162.550	1000
Ft. Wayne	WXJ-58	162.550	1000
Indianapolis	KEC-74	162.550	1000
Lafayette	WXK-74	162.475	100
Southbend	WXJ-57	162.400	1000
Terre Haute	WXK-72	162.400	1000

Location	Call Sign	Frequency MHz	Power Watts
IOWA			
Cedar Rapids	WXL-61	162.475	1000
Des Moines	WXL-57	162.550	1000
Dubuque	WXL-64	162.400	1000
Fort Dodge (not installed)			
Sioux City	WXL-62	162.475	1000
Waterloo	WXL-94	162.550	1000
KANSAS			
Chanute	WXK-95	162.400	400
Colby	WXK-96	162.475	600
Concordia	WXK-94	162.550	1000
Dodge City	WXK-93	162.475	1000
Ellsworth	WXK-92	162.400	1000
Topeka	WXK-91	162.475	1000
Wichita	KEC-59	162.550	1000
KENTUCKY			
Ashland	KIH-39	162.550	1000
Bowling Green	KIH-45	162.400	1000
Covington	KIH-42	162.550	1000
Elizabethtown	TRNSL	162.400	10
Hazard	KIH-40	162.475	1000
Lexington	KIH-41	162.400	1000
Louisville	KIH-43	162.475	1000
Mayfield	KIH-46	162.475	1000
Pikeville	TRNSL	162.400	10
Somerset	KIH-44	162.550	1000

*From 162.475 to 162.425 on December 1, 1981
** May relocate.

Appendix B, Continued

Location	Call Sign	Frequency MHz	Power Watts
LOUISIANA			
Alexandria	WXK-78	162.475	400
Baton Rouge	KHB-46	162.400	700
Buras	WXL-41	162.475	1000
Lafayette	WXK-80	162.550	300
Lake Charles	KHB-42	162.400	500
Monroe	WXJ-96	162.550	1000
Morgan City	KIH-23	162.475	1000
New Orleans	KHB-43	162.550	1000
Sherveport	WXJ-97	162.400	1000
MAINE			
Dresden	WXM-60	162.475	100
Ellsworth	KEC-93	162.400	1000
Portland	KDO-95	162.550	500
MARYLAND			
Baltimore*	KEC-83	162.400	1000
Hagerstown	WXM-42	162.475	1000
Salisbury**	KEC-92	162.475	1000
MASSACHUSETTS			
Boston	KHB-35	162.475	200
Hyannis	KEC-73	162.550	300
Worcester	WXL-93	162.550	200
MICHIGAN			
Alpena	KIG-83	162.550	500
MICHIGAN, (Continued)			
Detroit*	KEC-63	162.550	330
Flint	KIH-29	162.400	1000
Grand Rapids	KIG-63	162.550	1000
Houghton	WXK-73	162.400	1000
Marquette	KIG-66	162.550	300
Onondaga	WXK-81	162.400	500
Sault Saint Marie**	KIG-74	162.550	300
Traverse City	KIH-22	162.400	330
MINNESOTA			
Detroit Lakes		162.475	100
Duluth	KIG-64	162.550	1000
International Falls	WXK-45	162.550	1000
Mankato	WXK-40	162.400	1000
Minneapolis	KEC-65	162.550	1000
Rochester	WXK-41	162.475	1000
St. Cloud	WXL-65	162.475	330
Thief River Falls	WXK-43	162.550	1000
Willmar	WXK-44	162.400	1000
MISSISSIPPI			
Ackerman	KIH-51	162.475	300
Booneville	KIH-53	162.550	700
Bude	KIH-48	162.550	400
Columbia	TRANS	162.400	30
Gulfport	KIH-21	162.400	330
Hattiesburg	KIH-47	162.475	1000
Inverness	KIH-50	162.550	500

*May relocate.
** Will relocate.

Appendix B, Continued

Location	Call Sign	Frequency MHz	Power Watts
MISSISSIPPI, (Continued)			
Jackson	KIH-38	162.400	1000
Meridian	KIH-49	162.550	200
Oxford	KIH-52	162.400	400
MISSOURI			
Camdenton	WXJ-90	162.550	1000
Columbia	WXL-45	162.400	1000
Hannibal	WXK-82	162.475	1000
Joplin/Carthage	WXJ-61	162.550	500
Kansas City	KID-77	162.550	1000
Sikeston	WXL-47	162.400	1000
Springfield	WXL-46	162.400	250
St. Joseph*	KEC-77	162.400	330
St. Louis	KDO-89	162.550	1000
MONTANA			
Billings	WXL-27	162.550	300
Butte	WXL-79	162.550	100
Glasgow	WXL-32	162.550	1000
Great Falls	WXJ-43	162.550	1000
Havre	WXL-53	162.400	300
Helena	WXK-66	162.400	1000
Kalispell	WXL-82	162.550	100
Miles City	WXL-54	162.400	300
Missoula	WXL-25	162.400	100

*May relocate.

Location	Call Sign	Frequency MHz	Power Watts
NEBRASKA			
Bassett	WXL-73	162.475	630
Grand Island	WXL-74	162.400	1000
Holdrege	WXL-75	162.475	1000
Lincoln	WXM-20	162.475	1000
Merriman	WXL-76	162.400	800
Norfolk	WXL-77	162.550	800
North Platte	WXL-68	162.550	1000
Omaha	KIH-61	162.400	1000
Scotts Bluff	WXL-67	162.550	1000
NEVADA			
Elko	WXL-28	162.550	100
Ely	WXL-69	162.400	100
Las Vegas	WXL-36	162.550	100
Reno	WXK-58	162.550	100
Winnemucca	WXL-29	162.400	100
NEW HAMPSHIRE			
Concord	WXJ-40	162.400	330
NEW JERSEY			
Atlantic City	KHB-38	162.400	500
NEW MEXICO			
Albuquerque	WXJ-34	162.400	330

Location	Call Sign	Frequency MHz	Power Watts
NEW MEXICO, (Continued)			
Clovis*	WXJ-35	162.475	100
Des Moines	WXL-90	162.550	100
Farmington	WXJ-37	162.475	100
Hobbs	WXJ-36	162.400	100
Las Cruces	WXL-91	162.400	100
Ruidoso	WXJ-38	162.550	100
Sante Fe	WXJ-33	162.550	100
NEW YORK			
Albany	WXL-34	162.550	1000
Binghamton	WXL-38	162.475	1000
Buffalo*	KEB-98	162.550	280
Elmira	WXM-31	162.550	1000
Kingston	WXL-37	162.475	1000
New York City	KWO-35	162.550	500
Rochester	KHA-53	162.400	500
Syracuse	WXL-31	162.550	1000
NORTH CAROLINA			
Asheville	WXL-56	162.400	250
Cape Hatteras	KIG-77	162.475	1000
Charlotte	WXL-70	162.475	200
Fayetteville	WXL-50	162.475	250
New Bern	KEC-84	162.400	1000
Raleigh	WXL-58	162.550	1000
Rocky Mount	WXL-59	162.475	1000

* Will relocate.

Location	Call Sign	Frequency MHz	Power Watts
NORTH CAROLINA, (Continued)			
Wilmington	KHB-31	162.550	1000
Winston-Salem	WXL-42	162.400	100
NORTH DAKOTA			
Bismarck	WXL-78	162.400	1000
Dickinson	WXL-80	162.400	800
Fargo	WXK-42	162.400	500
Jamestown	WXL-81	162.400	1000
Minot	WXL-83	162.400	1000
OHIO			
Akron	KDO-94	162.400	500
Caldwell	WXJ-47	162.475	500
Cleveland	KHB-59	162.550	500
Columbus	KIG-86	162.550	1000
Dayton	WXJ-46	162.475	300
Lima	WXJ-93	162.400	1000
Sandusky	KHB-97	162.400	1000
Toledo	WXL-51	162.550	100
OKLAHOMA			
Clinton	WXK-87	162.475	500
Enid	WXL-48	162.475	200
Lawton	WXK-86	162.550	1000
McAlester	WXL-49	162.475	1000
Oklahoma City	WXK-85	162.400	1000
Tulsa	KIH-27	162.550	500

Appendix B, Continued

Location	Call Sign	Frequency MHz	Power Watts
OREGON			
Astoria	KEC-91	162.400	330
Coos Bay	KIH-32	162.400	330
Eugene	KEC-42	162.400	80
Klamath Falls	WXL-97	162.550	100
Medford	WXL-85	162.400	1000
Newport	KIH-33	162.550	1000
Pendleton*	WXL-95	162.550	1000
Portland	KIG-98	162.550	330
Redmond**	WXM-43	162.475	100
Roseburg	WXL-98	162.475	100
Salem	WXL-96	162.475	1000
PENNSYLVANIA			
Allentown	WXL-39	162.400	250
Clearfield	WXL-52	162.550	500
Erie***	KEC-58	162.400	300
Harrisburg	WXL-40	162.550	250
Johnstown	WXM-33	162.400	250
Philadelphia	KIH-28	162.475	1000
Pittsburg	KIH-35	162.550	1000
State College	WXM-59	162.475	100
Wilkes-Barre	WXL-43	162.550	250
Williamsport	WXL-55	162.400	250
PUERTO RICO			
Maricao	WXJ-69	162.550	1000
San Juan	WXJ-68	162.400	1000

*May relocate.
**Not installed.
***May raise antenna.

Location	Call Sign	Frequency MHz	Power Watts
RHODE ISLAND			
Providence	WXJ-39	162.400	500
SOUTH CAROLINA			
Beaufort	WXJ-23	162.475	1000
Charleston	KHB-29	162.550	1000
Columbia	WXJ-20	162.400	1000
Florence	WXJ-22	162.550	1000
Greenville	WXJ-21	162.550	1000
Myrtle Beach	KEC-95	162.400	1000
Sumter	TRANSL	162.475	10
SOUTH DAKOTA			
Aberdeen	WXM-25	162.475	1000
Huron	WXM-27	162.550	250
Pierre	WXM-26	162.400	700
Rapid City	WXM-63	162.550	200
Sioux Falls	WXM-28	162.400	1000
TENNESSEE			
Bristol	WXK-47	162.550	500
Chattanooga	WXK-48	162.550	1000
Cookeville	WXK-61	162.400	200
Jackson	WXK-60	162.550	1000
Knoxville	WXK-46	162.475	1000
Memphis	WXK-49	162.475	1000
Nashville	KIG-79	162.550	1000
Shelbyville	WXK-63	162.475	200
Waverly	WXK-62	162.400	1000

Appendix B, Continued

Location	Call Sign	Frequency MHz	Power Watts
TEXAS			
Abilene	WXK-29	162.400	100
Amarillo	WXK-38	162.550	1000
Austin	WXK-27	162.400	1000
Beaumont	WXK-28	162.475	1000
Big Spring	WXK-37	162.475	1000
Brownsville	KHB-33	162.550	1000
Bryan	WXK-30	162.550	1000
Corpus Christi	KHB-41	162.550	1000
Dallas	KEC-56	162.400	1000
Del Rio	WXJ-98	162.400	1000
El Paso	WXK-25	162.475	100
Fort Worth	KEC-55	162.550	330
Galveston	KHB-40	162.550	500
Houston	KGG-68	162.400	330
Laredo	WXK-26	162.475	1000
Lubbock	WXK-79	162.400	1000
Lufkin	WXK-23	162.550	1000
Midland	WXK-32	162.400	1000
Paris	WXK-20	162.550	1000
Pharr	KHB-33	162.400	1000
San Angelo	WXK-33	162.550	1000
San Antonio	WXK-67	162.550	1000
Sherman	WXK-22	162.475	1000
Tyler	WXK-36	162.475	1000
Victoria	WXK-34	162.400	1000
Waco	WXK-35	162.475	500
Wichita Falls	WXK-31	162.475	1000

Location	Call Sign	Frequency MHz	Power Watts
UTAH			
Cedar City	WXM-24	162.400	100
Logan	WXM-22	162.400	100
Salt Lake City	KEC-78	162.550	330
Vernal	WXM-23	162.400	100
VERMONT			
Burlington	KIG-60	162.400	1000
Windsor	WXM-44	162.475	400
VIRGINIA			
Heathsville	WXM-57	162.400	1000
Lynchburg	WXL-92	162.400	500
Norfolk	KHB-37	162.550	1000
Richmond	WXK-65	162.475	1000
Roanoke	WXL-60	162.475	200
WASHINGTON			
Neah Bay	KIH-36	162.550	330
Olympia	WXM-62	162.475	100
Seattle	KHB-60	162.550	330
Spokane	WXL-86	162.400	100
Winatchee	WXM-48	162.475	100
WEST VIRGINIA			
Charleston	WXJ-84	162.400	950
Clarksburg	WXJ-85	162.550	650

Appendix B, Continued

Location	Call Sign	Frequency MHz	Power Watts
WISCONSIN			
Green Bay	KIG-65	162.550	1000
Lacrosse	WXJ-86	162.550	1000
Madison	WXJ-87	162.550	1000
Menomonie	WXJ-88	162.400	1000
Milwaukee	KEC-60	162.400	1000
Wausau	WXJ-89	162.475	100

Location	Call Sign	Frequency MHz	Power Watts
WYOMING			
Casper	WXM-47	162.550	400
Cheyenne	WXM-37	162.475	100
Lander	WXM-61	162.475	1000
Rawlins	WXM-36	162.400	250
Rock Springs	WXM-35	162.550	500
Sheridan	WXM-46	162.475	100

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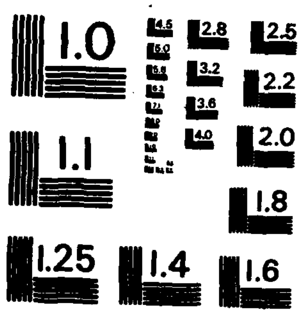


Appendix C

This appendix is reprinted here for information only showing a typical Encoder/Decoder used for activation of a siren system. It is reprinted here with the permission of Whelen Engineering Company.

WHELEN 800 SERIES SIREN ACTIVATION AND CONTROL SYSTEM

The Whelen 800 Series Warning Siren Activation and Control System is designed utilizing dual-tone multi-frequency signaling (DTMF). The control equipment consists of the Whelen Model E-801-8 Encoder and Whelen's Model D-802-8 Decoder. (Figures 1 & 2)

Utilizing DTMF signaling, each component of an address code is represented by two tones; a high tone and a low tone produced simultaneously. Encoded transmissions can be sent via voice grade telephone line or via radio carrier. Unlike digital signaling, DTMF signaling via radio transmission is highly resistant to atmospheric interference and is very reliable in a single transmission.

The Whelen 800 Series Warning Siren Activation and Control System controls are designed to accomodate a data format (address code) eight digits in length. The eight digit code is divided into three components; the area code (3 digits), the address code (4 digits) and the command code (1 digit).

Feature	*Benefits*
Dual-Tone Multi-Frequency Signaling:	*--Security against false activation.* *--Highly reliable signaling method for radio transmission.*
Eight Digit Address Code:	*--Extensive system capacity.* *--The selection of 1 group of 10,000,000 stations or 1,000 groups of 10,000 stations possible. Other combinations or groups are possible.*
Transmission Rate:	*--The 800 series DTMF message is on and off the air within 460 milli-seconds, permitting use on systems with existing traffic.*
Command Capabilities:	*--Twelve commands and functions are possible with the 800 Series Encoder and Decoder.*
User Programming:	*--The 800 Series Encoding units are capable of different levels of user programming, permitting low cost user system modifications and unit field replacement.*
All Call:	*--Group activation and total system activation is possible as well as individual siren activation.*

SYSTEM DESCRIPTION

Signaling:

Dual-tone Multi-frequency signaling is utilized. Transmissions can be sent via voice grade telephone lines or a radio carrier. Transmission rates of 7.14 to 16.6 digits per second may be used. Each digit in the signaling is represented by a high tone and a low tone selected from a 2 of 7 format as represented in Figure 3. For example; the digit 1 would be represented by a high tone of 1209 Hz and a low tone of 697 Hz.

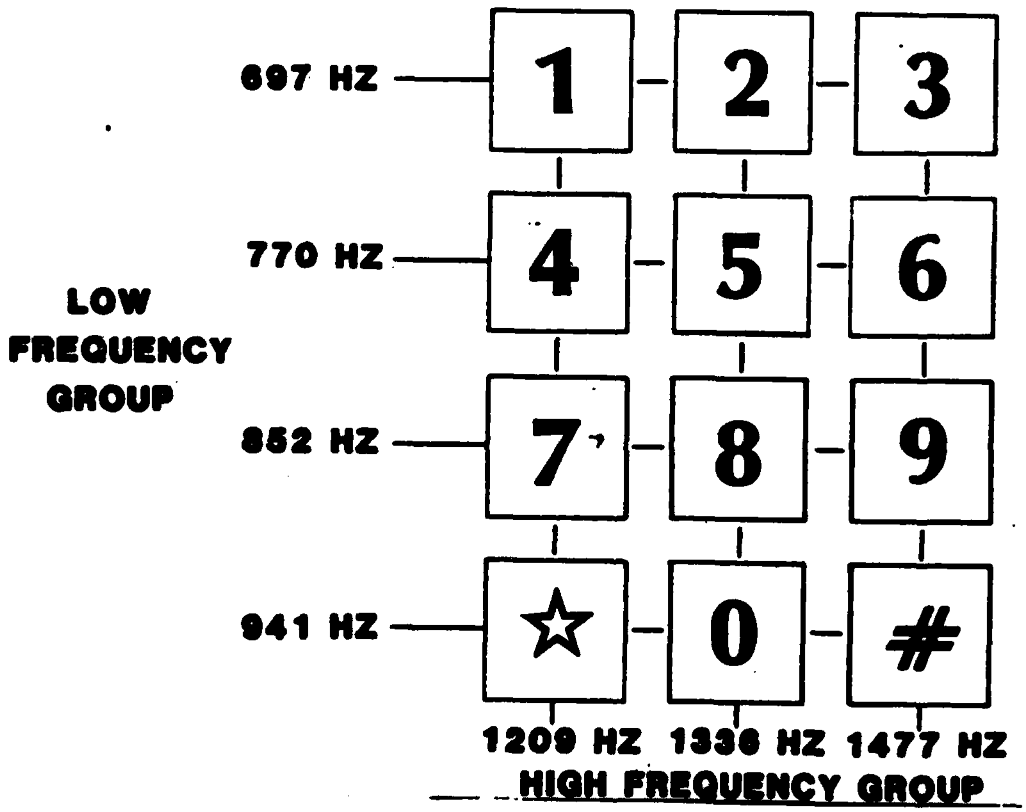


FIGURE 3

Data Format:

The address code is eight digits in length (Figure 4). Digits 0 through 9 and the symbols * and # can be sent. The first three digits represent the area code; the next four digits are the address code of the individual siren and the remaining digit is the command code, which can activate up to twelve functions.

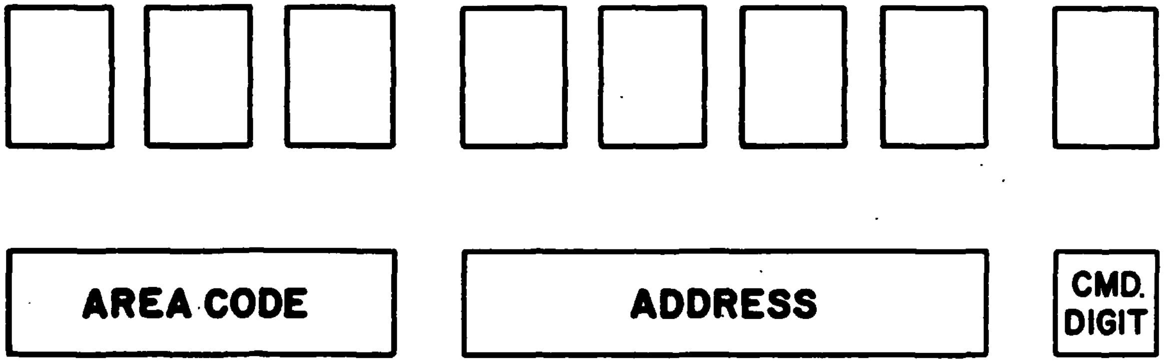


FIGURE 4

Transmission:

Each digit of the eight digit address is sent for 40 milli-seconds, with a separation of 20 milli-seconds between digits. This transmission is represented in Figure 5. Both the high tone and low tone representing each digit must be detected simultaneously for a minimum of 18 milli-seconds before the decoder will accept them as representing one digit of the code. Both tones must then clear prior to the transmission and reception of the next digit. Since each digit is transmitted for 40 milli-seconds and recognition requires only 18 milli-seconds within each digit's transmission, it is unlikely that RF interference could disable the encoded message.

System Design and Control:

With an area code of three digits (1000 area codes) and an address code of four digits, the following grouping of systems is possible: See Figure 6.

On the Model E-801-8 Encoder, the area code is pre-programmed internally. The four digit address code is thumb-wheel selectable, although any digit of the address code may be programmed internally, providing sub-operators in a group with only limited access to the system.

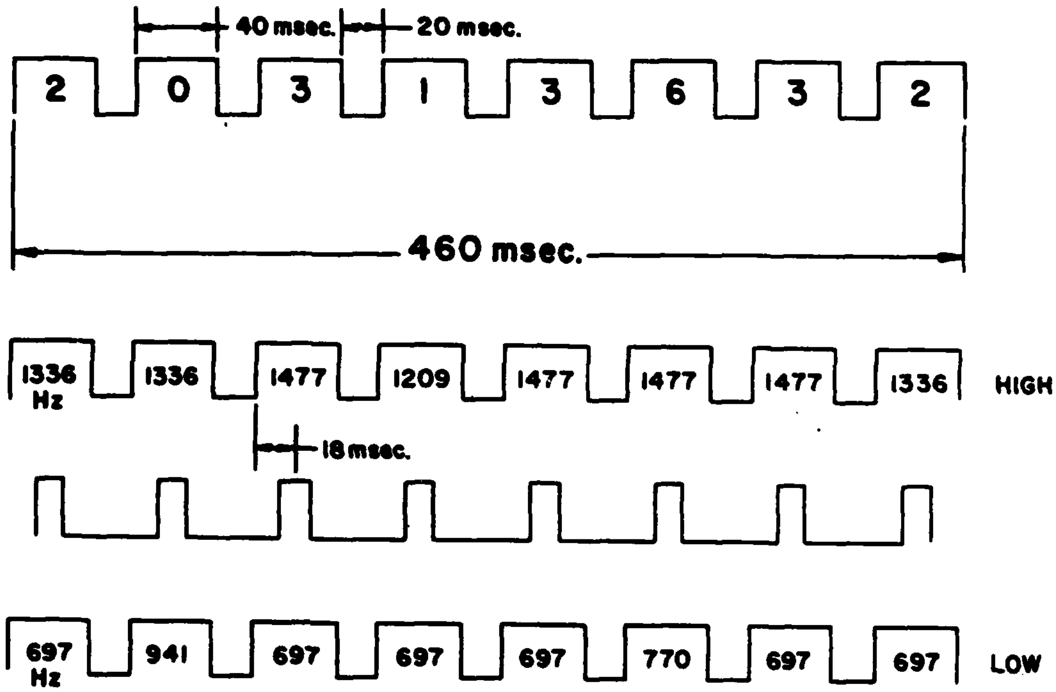


FIGURE 5

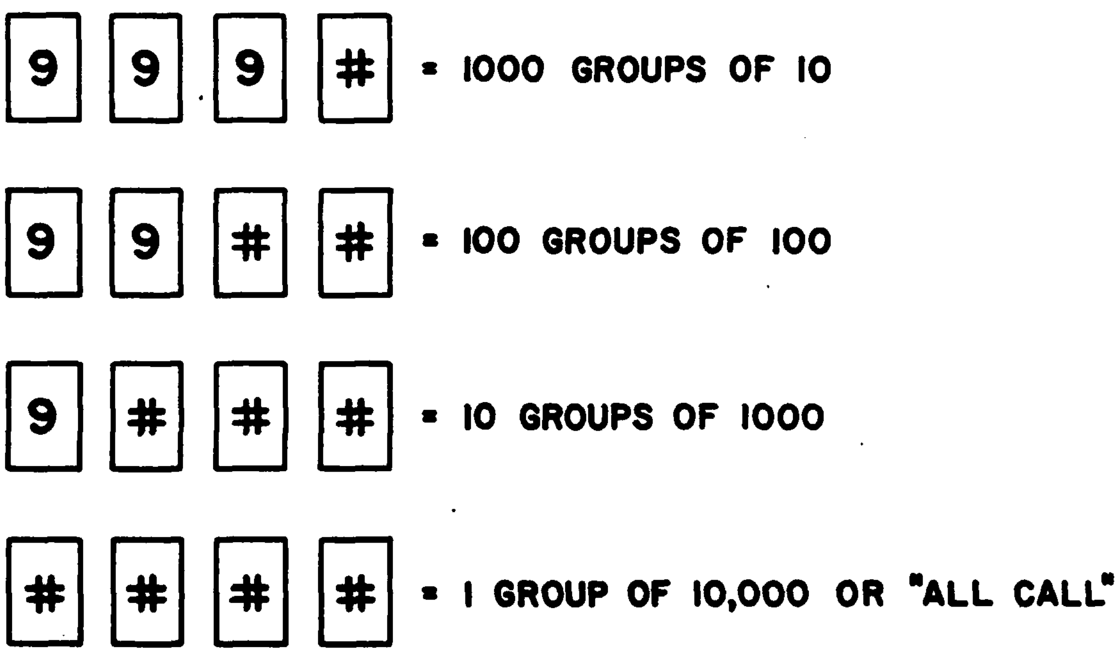


FIGURE 6

An "all call" feature is possible for any of the four digits presented in the address code. This feature is possible by using a substitute number(s) in the address code.

Address code assignment is generally determined by plotting a system by area, radii, quadrants and sectors (See Figures 7, 8 and 9). The example shown in Figures 7, 8 and 9 depicts a geographical area assigned the area code 203. This area is divided up into six radii which are divided into four quadrants that are further segmented into four sectors each. In each sub-area shown, a maximum of ten sirens can be placed. The access code of 203-1363 is activating the third siren in radius six of sector three in quadrant 1 of area 203.

Substitute Number:

Group Call or All Call of units in an area or a sub-group is possible by the use of a substitute number in the address code, represented by a # symbol. For example: If all sirens in radius six, sector three in quadrant one are to be activated in area 203, the address code would be represented as 203-136#. For activation of all the sirens in sector three in quadrant 1, an access code of 203-13## would be used. If all the sirens in radius six are desired to be activated, an access code of 203-##6# would be sent.

Signal Security:

The area code for a system is hard wired and not thumb-wheel selectable. The area code is designed not to accept a substitute number. An area code will be assigned only once within a frequency's maximum area or propogation. All Call will still be available in the address code for all sirens assigned to an area, but the activation of a system by the repetitive use of a substitute number for seven digits will not be possible. Any other activation of the system will occur only when the exact eight digit code is transmitted in a precise time frame. The method for signal detection and acceptance or rejection is detailed further in the Model D-802-8 Decoder description.

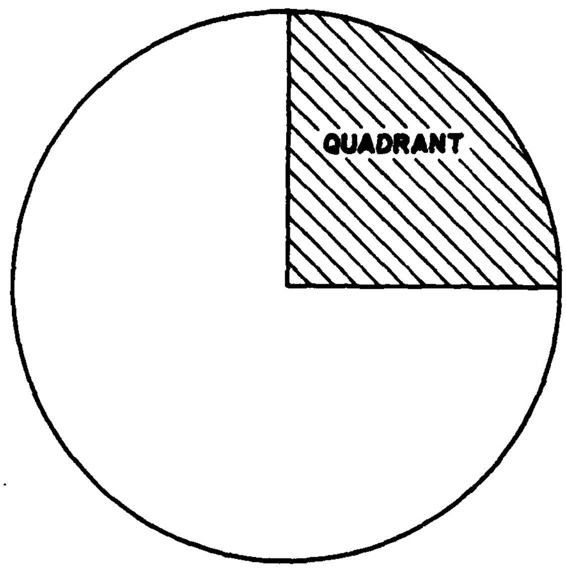


FIGURE 7

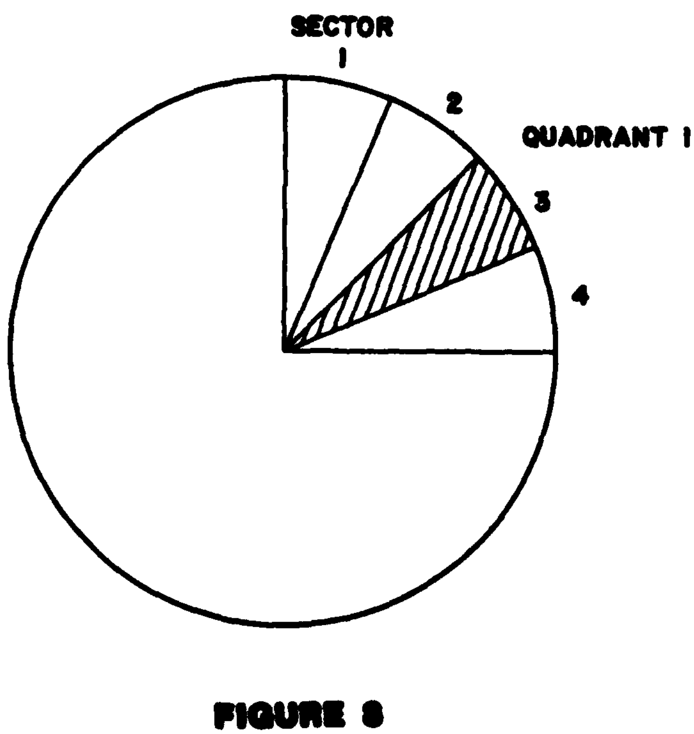
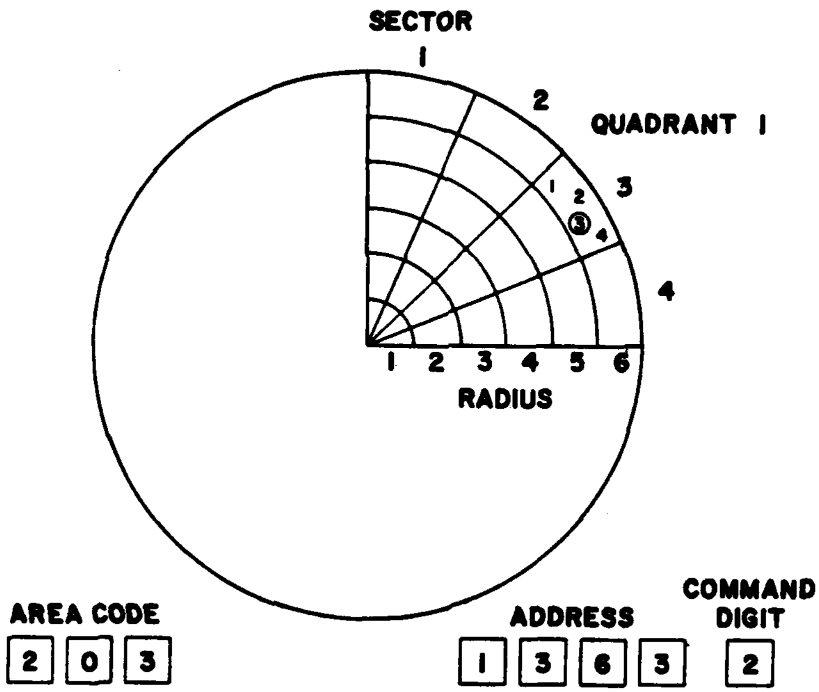


FIGURE 8



SECTOR
1
2
QUADRANT 1
3
1
2
3
4
4
1 2 3 4 5 6
RADIUS
AREA CODE
2 0 3
ADDRESS
1 3 6 3
COMMAND DIGIT
2

FIGURE 9

MODEL E-801-8 ENCODER

Description:

The Model E-801-8 is capable of accessing up to ten million individual locations or stations. It can control up to twelve functions at each location. Using dual-tone multi-frequency (DTMF) coding, a single transmission mode can be used with high reliability and security. (See Figure 10) Twelve numbers can be utilized for each digit transmitted. Voice grade telephone lines or radio carrier are normally used for transmission to Model D-802-8 Decoders at remote stations.

*The Encoder transmits eight digits in serial format. The first three digits represent the area code assigned to that geographical area that all the remote stations are located in. Each remote station is assigned a four digit address code which must be received in its proper sequence. For example; if the Decoder was assigned the address code of 1363, the first digit, the number 1, must be transmitted first, then the 3, then the 6 and then the 3. Other remote stations will reject that address as invalid. The last digit transmitted by the Encoder is the command function. This last digit controls the equipment at the remote station. Any number from 0 to 9 and * may be used and assigned a particular function. The normal assignments are: (See Figure 1)*

1--Wail	*7--Rotate to North*
2--Attack	*8--Rotate to East*
3--Alert	*9--Rotate to South*
4--PA	*0--Rotate to West*
5--Air Horn (Increment CCW)+	**--Reset (CLR)*
6--HI/LO (Increment CW)+	

+Incrementing 45° in the clockwise and counter-clockwise is an available option that replaces Air Horn and Hi/Lo functions.

The Model E-801-8 Encoder has a data rate of 7.14 to 16.6 digits per second. The dual tones are transmitted for 40 milli-seconds with an inter-digit time of 20 milli-seconds for a total of 60 milli-seconds per digit. At this rate, 460 milli-seconds is required to access a remote station. The Encoder has a delaying circuit that activates the transmitter, permitting the transmitter and receiver to stabilize before receiving the eight digit access code. This delay is adjustable in the encoder and must be added to the signal time to determine the total time required to transmit one command signal.

To allow activation of groups of remote stations, an "all call" number, normally the # sign, is used. This "#" sign can be substituted for any or all numbers in the four digit address code. The address is selected by means of up to four thumb-wheel switches on the Encoder. The quantity of thumb-wheel switches is dependent upon the accessing capability desired for an individual encoder. Each switch has eleven

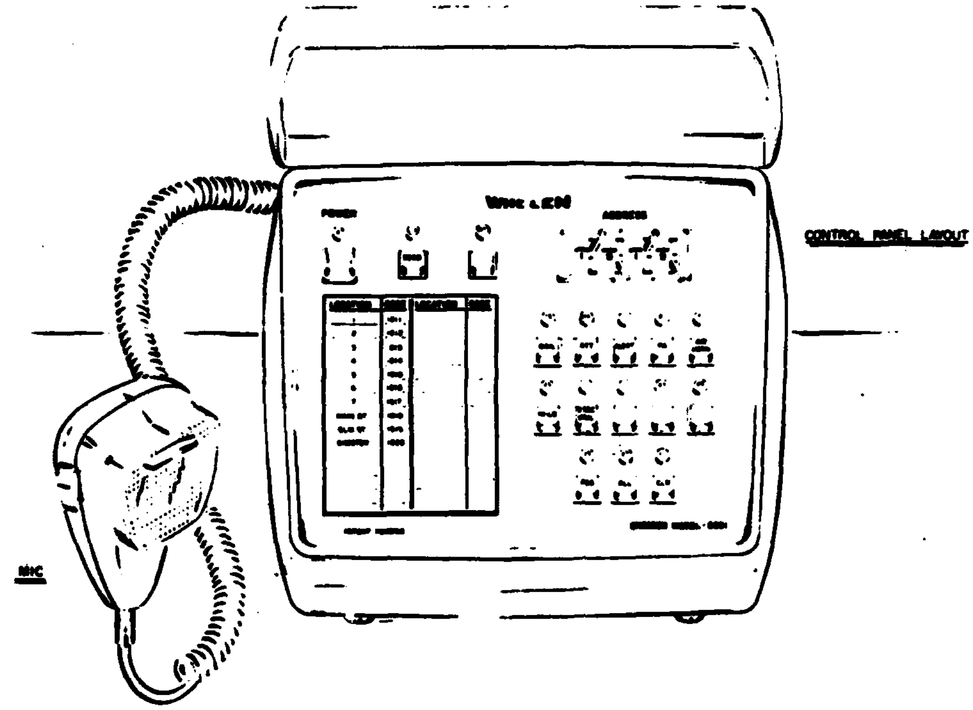


FIGURE 10

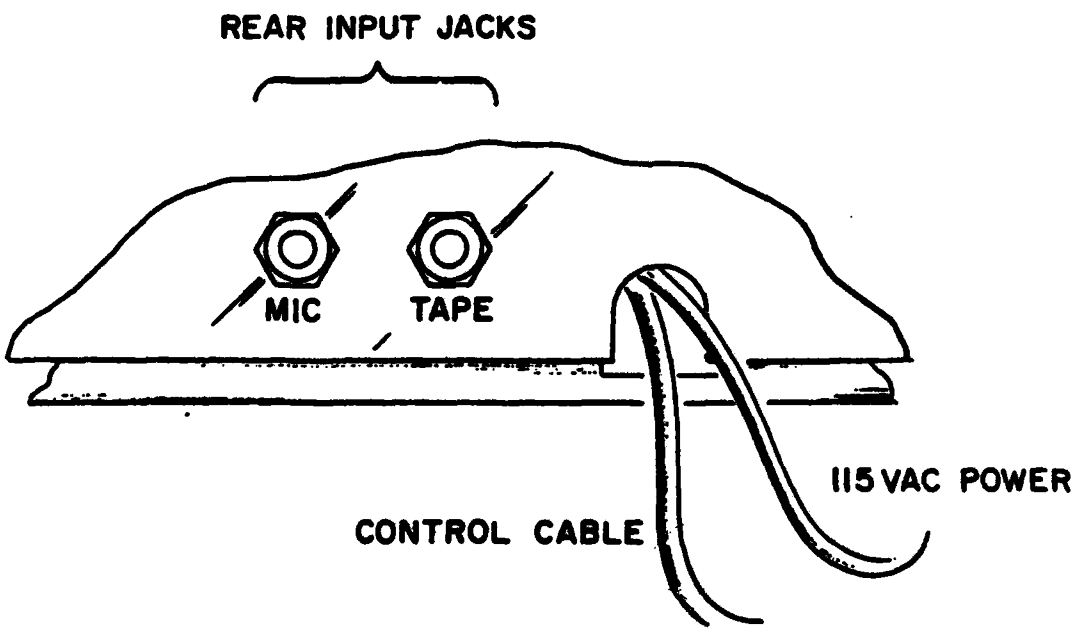


FIGURE 11

positions, 0 to 11, with position 11 used for the "#" sign. If all four switches were placed in 11-11-11-11, all remote stations in that encoder's area code would respond to that address. If the switches were set up for 1-3-6-11, only those stations that had the first three numbers of the address would respond. If the switches were set up for 1-11-6-11, any station that had a 1 for the first digit and a 6 for the third digit of the address would respond. Other stations located elsewhere in the system would not respond because their programming was different.

Figures 10 and 11 show the encoder with microphone, tape recorder jack, power cord and control cable. The encoder has an off/on switch with indicator and operates from 115 VAC. The address selector is in the upper right corner. The Encoder will transmit these digits as the fourth, fifth, sixth and seventh digits sent unless "all" has been pressed, which causes four "#"s to be sent. In small systems, the first two address digits may be permanently selected by jumpers, as # or other digits so that only the third and fourth digits need be selected. The three digit area code is hard wired internally and will not be field programmable.

The two rows of five push buttons set up the command digits 1 through 9 and 0. These are usually labeled with their functions rather than numbers. The LED indicator above the pressed button flashes until the encoder is reset.

The pre-check button causes a modification of the third digit of the area code to a pre-determined number. The eight digit code is transmitted with the modified area code and is received by the system status map (optional). The pre-check button is a momentary button and remains in effect only for the time it is depressed by the operator. The dual tones for the last digit will remain on the air as long as the pre-check button is depressed. When the status map receives the modified eight digit code, it will accept the modified code and display the remote station or stations addressed by the operator for activation and confirm the selection. The remote stations will reject the modified area code as invalid and not activate. When the pre-check button is released, the last digit's dual tones are dropped off the air, the status map resets and the area code is restored.

The send button causes the area code, the address code and the command code chosen to be sent. This function activates the selected siren units and causes the selected command function to be activated.

The reset button causes reset of the encoder. The all button causes the # digit to be substituted for all four address digits. The clear button causes the * to be sent as a command digit, thus resetting the addressed remote unit(s).

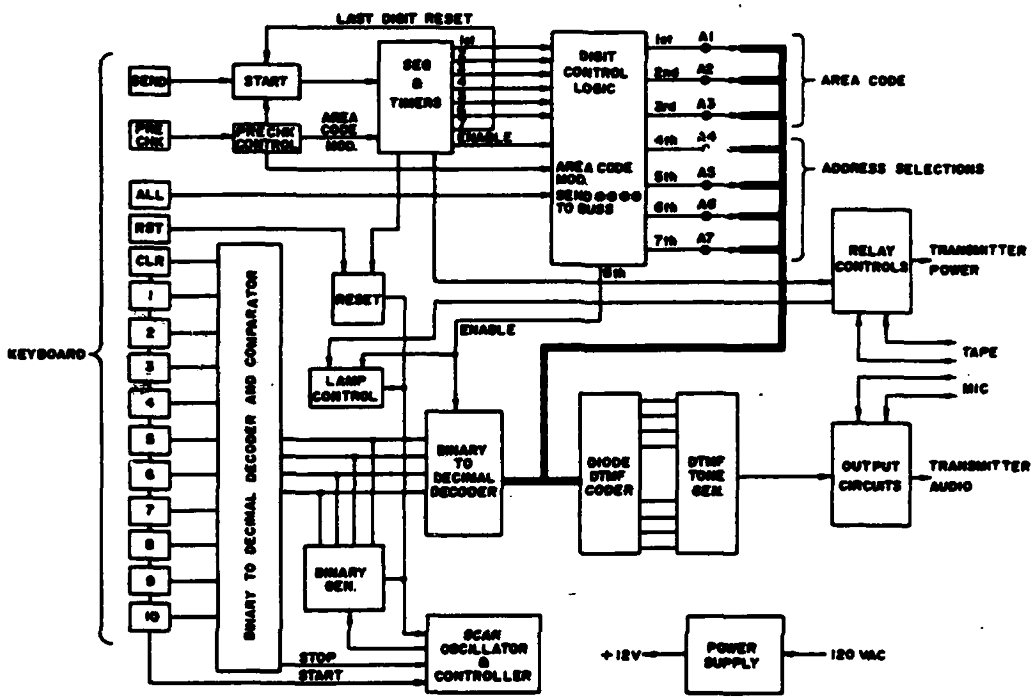
Installation:

The power requirement of the Model E-801-8 Encoder is approximately 10 watts at 115 VAC, 60 Hz. The unit is equipped with a power cord which may be plugged into a standard outlet. Two sets of relay contacts are available to permit transmitter warmup before tone transmission begins. These are relays K3 and K4, each of which has a wiper, NO and NC pins. Relay K4 is normally connected to the transmitter causing it to be brought out of standby into transmit mode. Relay K3 may be used to activate a sub-carrier tone so that receivers other than those in the siren system will squelch the DTMF tones. Normally, the relay K4 contacts are available on the terminal strip.

The output cable has two floating leads, containing audio or tone signals, which should be connected to the transmitter audio input. The shield is connected to chassis ground. The audio leads are capacitor coupled and further isolated by a set of relay K3 contacts when the encoder is not in its transmit sequence. In order to provide proper decoding of DTMF tones, the tone level adjust, potentiometer R21, must be set so that 50% modulation is achieved during tone transmission. This may be set up by using a suitable RF receiver and adjusting for a deviation of 2.5 KHz.

The microphone connector has three contacts, one ground, one control and one signal. The control contact is used by the microphone switch and activates the transmitter and signal path. The audio level control, potentiometer R29, should be set to achieve 80% modulation.

The tape connector also has three similar input contacts. These can be connected to tape recorder audio control jacks. The tape level control, potentiometer R30, should be adjusted to achieve 80% modulation of tape recorded audio messages. When the tape is also used to input DTMF code tones, they must be recorded 6 dB lower in order to achieve 50% modulation during tone transmission.



LAST DIGIT RESET
SEND
START
SEQ & TIMERS
DIGIT CONTROL LOGIC
AREA CODE
ADDRESS SELECTIONS
PRE CHK
PRE CHK CONTROL
AREA CODE MOD.
ENABLE
AREA CODE MOD.
SEND TO BUSS
ALL
RST
CLR
RESET
RELAY CONTROLS
TRANSMITTER POWER
KEYBOARD
ENABLE
LAMP CONTROL
TAPE
MIC
BINARY TO DECIMAL DECODER AND COMPARATOR
BINARY TO DECIMAL DECODER
DIODE DTMF CODER
DTMF TONE GEN.
OUTPUT CIRCUITS
TRANSMITTER AUDIO
BINARY GEN.
SCAN OSCILLATOR & CONTROLLER
STOP
START
+12V
POWER SUPPLY
120 VAC

FIGURE 12

Figure 12 shows a block diagram of the encoder. The principal circuits are described below.

The address selectors are thumb-wheel switches which connect the "A" pins to the decimal buss. They can code the decimal values 1, 2, 3, 4, 5, 6, 7, 8, 9, 0 and # (substitute number) onto the buss for the fourth, fifth, sixth and seventh digits transmitted.

*The keyboard provides for operator selection of the eighth (command) transmitted digit. Pressing a digit key starts the scan oscillator which interrogates each key until it finds the one pressed. The associated LED then flashes to indicate the function selected. The digits 1, 2, 3, 4, 5, 6, 7, 8, 9, 0 and * (decoder reset) can be generated and are strobed onto the buss as the eighth digit. In addition, the keyboard can reset the encoder, provide the all call option and pre-check the coding on the status display map.*

The scan oscillator and controller starts a 4 bit binary scan of the keyboard. The binary words are converted to decimal and the keyboard is interrogated until the button pressed is found. The scan oscillator is then stopped so that the binary representation of the selected digit is available. When the eighth digit is called for, a binary to decimal decoder strobes the digit onto the decimal buss.

The keyboard scanner consists of four flip-flops which count down in an inverted binary sequence to generate all possible 4 bit binary combinations under control of clock pulses from the scan oscillator. A binary to decimal converter raises each keyboard digit line until the one pressed is found. The scanner then stops and holds the binary value.

The start circuit responds to the pressing of pre-check or send keys by starting the delay and tone rate timers, removing power from the keyboard buss to prevent another command digit from being introduced and energizing the transmitter control relays.

The sequencers and timers provide for a warmup period for the transmitter and control the tone lengths and inter-digit times. After the warm up period, the timers drive a sequencer which sequentially drives eight lines to the digit control logic, each line controlling the transmission of a digit. If pre-check was selected, then the sequencer holds on to the eighth digit until the pre-check button is released. After transmission of the eighth digit, a last digit reset line resets the timers and sends a signal to the reset circuits.

The digit control logic provides for two options for each of the first seven digits. Either the four address pins are sequentially brought low or the all call digit, "#", can be selected. In addition, jumper programming can provide for fixed digit transmission as the first two address digits. The pre-check circuit controls which digit is sent as the third digit of the area code. The eighth digit is always the one on the binary buss, selected on the key board and decoded by the binary to decimal converter when strobed.

The pre-check control stops the sequencer on the eighth digit and enables area code third digit modification when the pre-check key is depressed.

The tone generator produces the appropriate DTMF tones in response to the digit present on the decimal buss using a diode matrix coder. Tones representing the digits 1, 2, 3, 4, 5, 6, 7, 8, 9, 0, * and # are generated in a 2-of-7 format as shown in Figure 3.

The relay controls provide for activation of the transmitter by the start circuit, microphone or tape switches. In addition, they activate the microphone or tape audio circuits when microphone or tape switches are closed. The send light is also lit by this circuit.

The output circuits consist of two amplifiers for boosting the DTMF, microphone or tape signals and potentiometers for controlling each. The audio output is transformer matched and capacitor isolated to provide floating audio leads to the transmitter.

The reset circuit provides for reset of the encoder during power on or when reset is pressed. In addition, two automatic reset functions, command or all, may be programmed to occur when the tone transmission is complete. The reset circuit also controls the flash circuit for the digit button lamps.

The power supply provides for 12 VDC regulated to the circuits from 115 VAC, 50 Hz input. An off/on switch is provided with an on indicator lamp.

MODEL E-801-8 ENCODER SPECIFICATIONS

Electrical Input:

Power	115 VAC, 60 Hz, 10w
Microphone	Gnd, signal, switch control
Tape Recorder	Gns, signal, switch control

Electrical Output:

DTMF Tone	Audio level adjustable 10/20 digits/second
Audio	Audio level adjustable

Control:

Relay	NO/NC contacts

Coding:

Transmission	DTMF 2-of-7 format, 8 digits

Environmental:

Operating Temperature	-30°C to +85°C
Storage	-60°C to +100°C
Humidity	0 to 95%, non-condensing

Physical:

Dimensions	10" X 10" X 6"
Weight	4 lbs.

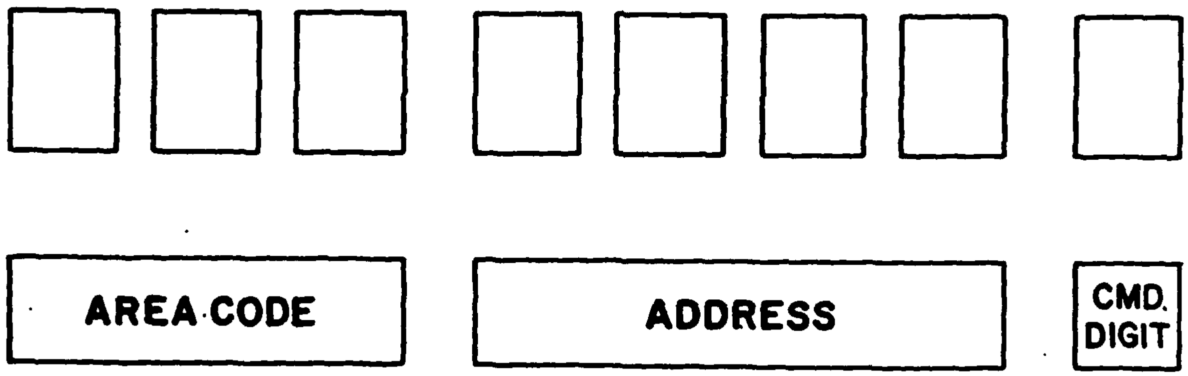


FIGURE 13

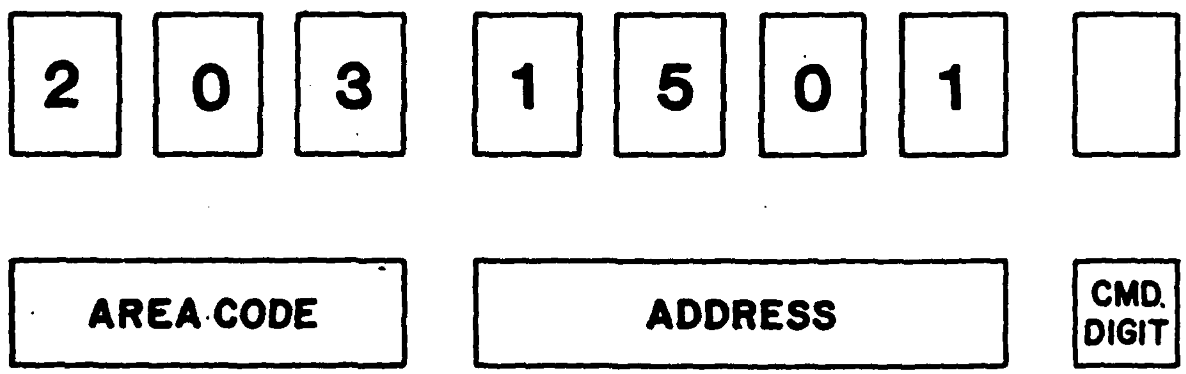


FIGURE 14

MODEL D-802-8 DECODER

The Whelen Model D-802-8 Tone Decoder was designed for the remote control of a siren unit. Signal integrity, reliability and security against false activation were priorities taken into consideration in the design of this equipment. The D-802-8 Decoder may be used to control a siren in a small system or a siren in a system of thousands of sirens.

Eight digits or numbers are used to address the decoder. The first seven digits are used for the "address" and the eighth or last digit is used as a command signal to provide control of the remote siren. The eight digit code is divided into three groups. Figure 13.

The first three digits, group 1, are used for an area code. Up to 1,000 area codes can be provided. The next four digits, group 2, are used as the address code. The four digit address code permits selection of up to 10,000 different sirens. The eighth digit, group 3, is used to control the siren. Twelve different command functions can be used.

Each decoder is assigned an area code and an address code. The area code is assigned to a complete system, while the individual siren is assigned its own address code. Area codes can be assigned to different systems throughout the country, thus preventing duplication of address numbers on the same frequencies, preventing false activation of the siren. By assigning area codes to different regions of the country, and with transmitters on different frequencies, the probability of false activation of a siren is very low. The area code and address code on the D-802-8 decoder can be re-programmed in the field if the change is desired. The decoder will only respond to its own address. When the first number of the area code is received, it is detected and compared to the first number programmed in the decoder. If the first number compares to the program, the decoder will accept it and wait for the second number of the area code to arrive. If the first number does not compare with the number programmed in the decoder, it is rejected along with the remainder of the area code and address code. Figure 14 depicts a typical address number of a decoder. The area code is assigned the number 203 and the address is 1501.

The first digit that the decoder receives must be a 2 followed by a 0 and then a 3 and then by the address code 1501. As each number or digit is received by the decoder, it is compared to its respective number programmed in the decoder. The area code and address code must compare, otherwise the entire address is rejected as an invalid signal. The decoder will not set up for a command digit unless a valid address is received. This provides for high security of the system.

	AREA CODE			ADDRESS CODE				COMMAND
SIREN 1	2	0	3	1	5	0	0	
SIREN 2	2	0	3	1	5	0	1	
SIREN 3	2	0	3	1	5	0	2	
SIREN 4	2	0	3	1	5	0	3	
SIREN 5	2	0	3	1	5	0	4	
SIREN 6	2	0	3	1	5	0	5	
SIREN 7	2	0	3	1	5	0	6	
SIREN 8	2	0	3	1	5	0	7	
SIREN 9	2	0	3	1	5	0	8	
SIREN 10	2	0	3	1	5	0	9	
ALL	2	0	3	1	5	0	#	

FIGURE 15

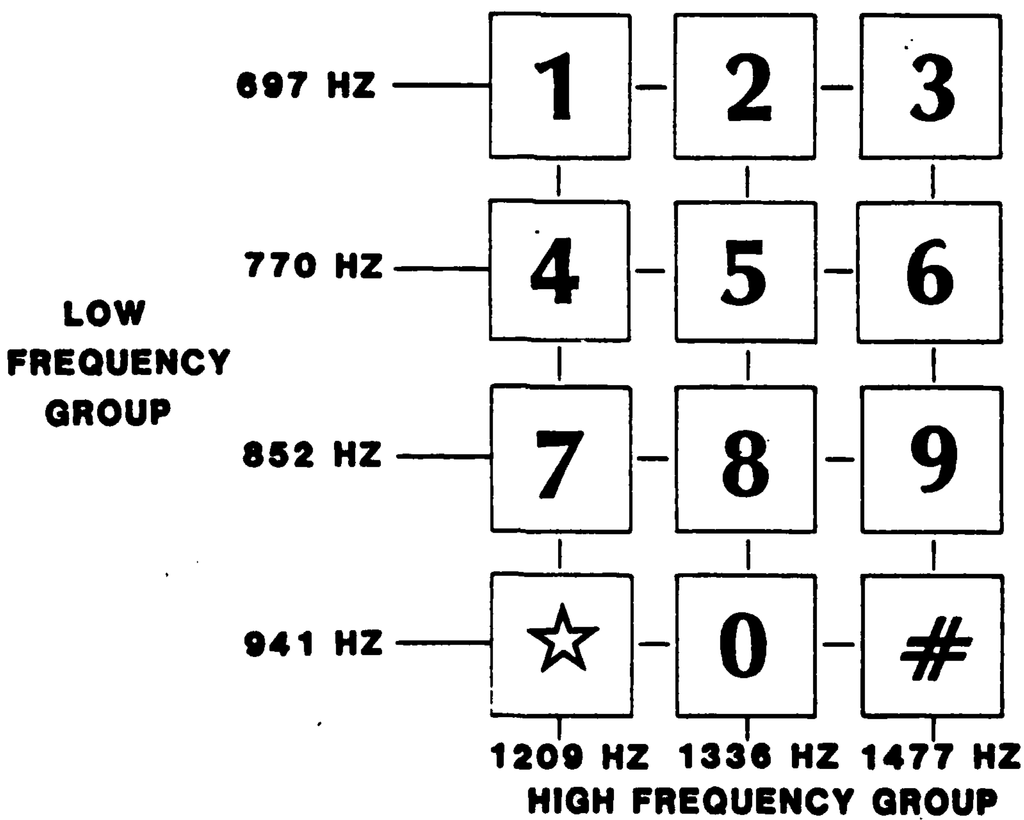


FIGURE 16

The decoder is very flexible in its application. It can control a single siren or groups of sirens. By using a substitute number in the address, various groups can be selected. This substitute number is the "#" sign. It can be substituted for any or all numbers in the address code. The area code must be dialed exactly. The area code will not respond to a substitute number; thus the following groups can be selected:

1,000 different area codes
1,000 groups of 10 sirens
100 groups of 100 sirens
10 groups of 1,000 sirens
1 group of 10,000 sirens

An example in using the substitute number in a small system, consisting of ten sirens, is shown in Figure 15. The area code is assigned the number 203.

The first three numbers of the address are 1, 5 and 0. The fourth number of the address is from 0-9: 0 for siren #1 and 9 for siren #10. Each siren has its own address code. The first three numbers of the address code are the same with the exception of the last digit being from 0-9. When the substitute "#" is used for the last number, all sirens will respond to the command signal given. Thus, in this system of ten sirens, any one of ten sirens or all ten sirens can be controlled by a single command from the central control station.

The Model D-802-8 Decoder was designed using high-speed dual-tone multi-frequency (DTMF) signals. These signals consist of seven tones in the audio range from 697 Hz to 1477 Hz (Figure 16).

Four tones are in the low band and three are in the high band. Unlike using two tones sequential signaling, where a single tone is received for a pre-determined period of time and then followed by a second tone, DTMF receives two tones simultaneously. Each tone is transmitted for 40 milli-seconds with 20 milli-seconds between tones. 460 milli-seconds is required to transmit the eight digit address and command tone. Figure 17.

When the DTMF signal arrives at the input of the decoder, the signal is processed before being decoded. The two simultaneously arriving tones are separated by two band pass filters into the low band frequencies 697 Hz to 941 Hz and into the high band frequencies 1209 Hz to 1633 Hz. These band pass filters reject any interference from a dial tone being transmitted or from a private line signal that may be used. The output of each band pass filter is further processed by a level detector and a hard driven amplifier providing AGC. The output of the hard driven amplifiers is a square wave with a constant amplitude.

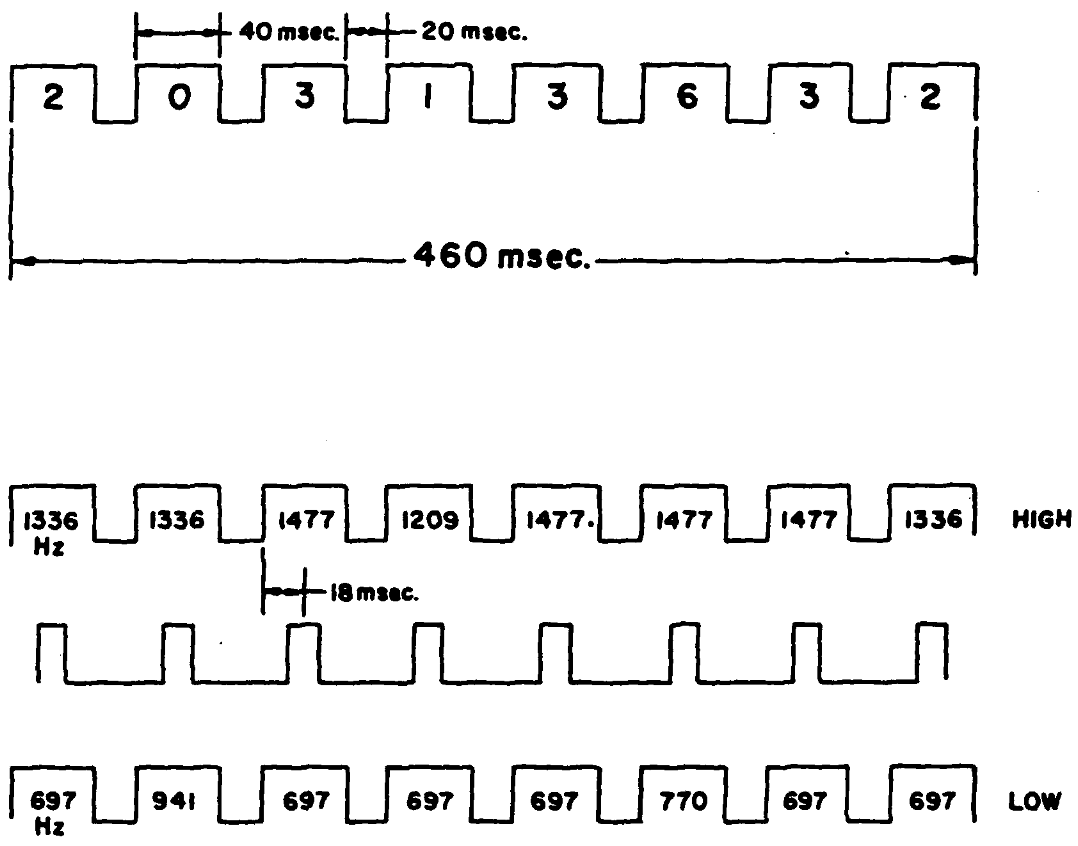

40 msec.
20 msec.
2 0 3 1 3 6 3 2
460 msec.
1336 Hz
1336
1477
1209
1477.
1477
1477
1336
HIGH
18 msec.
697 Hz
941
697
697
697
770
697
697
LOW

FIGURE 17

Although incoming signals vary in level, the output of the hard driven amplifier remains constant. The outputs of the hard driven amplifiers are fed to two control gates before being decoded. These two control gates are controlled by the envelope detector. Many filters exhibit a ringing characteristic at their outputs. This reduces the speed of operation. The envelope detector consists of two sample and hold circuits and a comparator. The envelope detector input is connected to the output of the low band filter. When a tone is received at the output of the filter, it is rectified and the peak signal is stored by the sample and hold circuits and then fed to the comparator. The comparator in turn enables the control gates feeding the tone decoder. The tones are being decoded as long as the gates are enabled. When the tone to the low band filter is removed, the output slowly decays, due to the ringing characteristic of the filter. When the output reaches one half of its former amplitude, the comparator will disable the control gates. The tones are decoded by 8 passive tuned circuits; four in the low band of frequencies and four in the high band of frequencies. Figure 18 shows a block diagram of the input processing and decoder circuit.

When a digit is received, a number 1 for example, this is made up of two frequencies; 697 Hz for the low tone and 1209 Hz for the high tone. The low tone, 697 Hz, is decoded by the low band decoder, producing an output of a constant level. This is rectivied and filtered and fed to a level detector. The output of the decoder is a sine wave of a fixed amplitude. The threshold of the level detector is set to respond from peak level to -3 dB below peak. If the signal is of poor grade and does not obtain the level required, no output is produced. The high tone, 1209 Hz, is also simultaneously being detected. The output of each level detector is OR gated together to reproduce the number 1 that was transmitted. Both tones must be present to obtain the number 1. By using seven tones, four in the low band of frequencies and three in the high band of frequencies, twelve numbers can be produced, always using one low tone and one high tone.

Both tones for each digit in the address must be present for a minimum of 18 milli-seconds before a valid tone is accepted. An output from the low group of frequencies and an output from the high group of frequencies is AND gated together. The AND gates produce an output if both low and high tones are present for 18 milli-seconds. At the end of 18 milli-seconds, a strobe pulse is produced. The data is stored at that point only. Either the low or high tone can be partially or totally destroyed and still receive a valid signal. The digit is being transmitted by the encoder for 40 milli-seconds. If one or both tones is destroyed during the first 20 milli-seconds, 20 milli-seconds is left to provide a valid signal. Once a valid signal is produced, no following signal can be received until both the low and high tones clear. This clearing occurs as the inter-digit time of 20 milli-seconds.

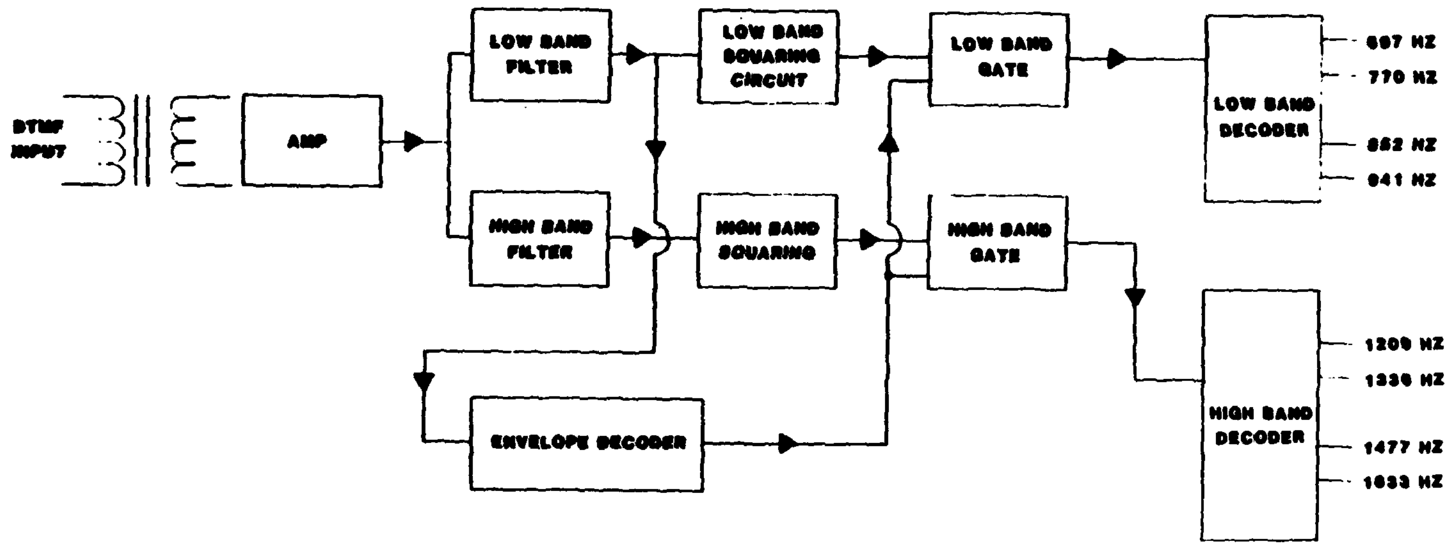

DTMF
INPUT
AMP
LOW BAND
FILTER
HIGH BAND
FILTER
LOW BAND
SQUARING
CIRCUIT
HIGH BAND
SQUARING
LOW BAND
GATE
HIGH BAND
GATE
ENVELOPE DECODER
LOW BAND
DECODER
HIGH BAND
DECODER
697 HZ
770 HZ
852 HZ
941 HZ
1209 HZ
1336 HZ
1477 HZ
1633 HZ

FIGURE 18

DECODER ADDRESS:

The decoder must be programmed with the correct area code and address so that proper access can be obtained. High security is obtained because each of the seven digits used for the area code and address code must arrive in the order they were transmitted. Using the area and address code in Figure 14, the first digit to be received is a 2, followed by a 0 and a 3 and then by the address code of 1501. A sequencing counter is used that advances one bit with each digit received. When the digit 2 is received, it is compared with the number 2 programmed in the decoder. If the digit being received is a 2, this will advance the sequence counter one bit, preparing it to receive the second digit. The next digit to be received is a 0. This is compared to the second digit programmed in the decoder, which is also a 0. If the second digit compares, this will advance the sequence counter one more bit. If a wrong number is received, the sequence counter is reset to its beginning and the remaining incoming digits will be rejected. Each digit is being compared with its associated number programmed in the decoder and must compare or be rejected at any point in the address. If a correct area and address code is transmitted, the sequence counter will advance until the eighth digit is received. The information contained in the last or eighth digit is stored to control the siren. Each digit is transmitted for 60 milli-seconds, 40 milli-seconds tone duration with 20 milli-seconds inter-digit time. The digits that follow must arrive within 100 milli-seconds or be rejected. This time period is only used when the decoder is operated with Whelen Model D-801-8 Encoder. For manual operation, this period must be extended.

TIMER:

Incorporated in the decoder is a timer that is activated when a valid command signal is received. This timer is normally set for three minutes. Longer periods can be used, depending upon the systems needs. Once a command output is activated, the timer will deactivate that output at the end of three minutes. The timer is automatically reset when a clear signal is received by the decoder.

The timer controls can be programmed for four time periods in addition to the 3-minute timer. These can be programmed in the field with jumper pins. Those times are; 5, 10, 30 and 90 second time periods. These timing periods can be varied to suit a particular system. Any or all command signals can be programmed except the clear command, which is factory set.

OUTPUT CONTROL:

Twelve outputs are provided by the decoder. These are open collector NPN transistors that can sink 50 ma of current to ground. Maximum voltage on the output should be under 50 volts. One of the outputs is used by the decoder as a clear signal. The collectors of two or more transistors can be connected in parallel to control the same command function, allowing the selection of different time-out periods.

AUDIO INPUT:

The tone decoder will operate over a 35 dB input range of voltage: -25dB minimum to a +10dB maximum. For optimum operation, a -10dB to a 0dB range is required. The audio input should be adjusted for this level. A signal greater than +10dB will over-load the input of the decoder and a signal less than -25dB would be insufficient to operate the decoder. In normal operation, no adjustment is required for the decoder.

RADIO APPLICATION:

A -10dB to 0dB signal is needed for the radio to operate the decoder and also to provide for PA. This audio level will vary, depending upon the percentage of modulation of the transmitter. Most FM or AM transmitters have circuitry to prevent over-modulation. There are limiter or clipper circuits that may cause distortion of the DTMF signals. To prevent this, the encoder signal feeding the transmitter should be set to produce no more than 50% modulation. Audio levels for PA use can be at full 100% modulation.

SECURITY & FALSE ACTIVATION:

Precautions againse false activation of the siren have been incorporated into the design of the D-802-8 Decoder. False activation can be caused by operating on a voice channel, atmospheric conditions, propagation, several users sharing the same channel, human error. Some of the features that guard against false activation in the D-802-8 Decoder are:

1. *Two tones must be received simultaneously; DTMF decoding.*
2. *Both tones must be present for a minimum of 18 milli-seconds for acceptance of each digit in the encoded message.*
3. *3 digit area code.*
4. *4 digit address code.*
5. *100 milli-seconds between tones, maximum.*
6. *Digits received must be in proper sequence and compare with the area code and address code programmed in the decoder, or be rejected.*
7. *Timer. In event of accidental activation by human error, the siren will time out automatically and shut down.*

MODEL D-802-8 TONE DECODER SPECIFICATIONS

ELECTRICAL:

Input Format:

Receive Audio	*30MV to 3V RMS each tone*
Signal Level:	*30MV to 3V RMS each tone*
CTCSS Rejection:	*40dB @ 400 Hz*
Impedance:	*600 ohms, DC Blocked*
Frequency Acceptance:	*±1.5% of Nominal Tone Frequency*
Tone Level Differential (Twist):	*12dB if the lesser tone is over 30MV*
Data Rate:	*.4 to 20 DPS set at factory for 16.6 DPS*
Code Capacity:	*3 digit area code 4 digit address code Field programmable Fixed length*
Inter-digit Interval:	*100 milli-seconds nominal 2.5 second optional*

Output Format:

Latched:	*1 of 12, timer controlled*
Timer:	*1 adjustable, 3 minutes maximum 4 programmable; 5 sec., 10 sec., 30 sec., 90 sec.*
Rating:	*50 ma @ 50 Volts DC maximum*
Circuits:	*Open collector transistors referenced to negative supply voltage. Transistors conduct as long as timer is operative or until reset command is received.*

Power Requirements:

Voltage:	*16 to 30 VDC*
Current:	*70 ma*

ENVIRONMENTAL:

Temperature:

Operating:	*-35°C to +85°C*
Storage:	*-65°C to +100°C*

PHYSICAL:

Dimensions:	***12.5" X 7" X 3"***
Weight:	***2.5 Lbs.***

Appendix D

This Appendix is reprinted here for information only. It is part of a document entitled <u>Acoustic Noise Measurements</u> by Brüel & Kjaer, January 1979 and is reprinted with their permission.

2. THE PHYSICAL PROPERTIES OF NOISE

2.1. VIBRATIONS AND WAVES

Acoustic Noise is usually defined as unwanted sound; an undesirable by-product of society's normal day-to-day activities. In physical terms, sound is the mechanical vibration of a gaseous, liquid or solid elastic medium through which energy is transferred away from the source by progressive sound waves. Whenever an object moves or vibrates, a small proportion of the energy involved is lost to the surrounding medium as sound.

Let us consider a small particle of the medium, large enough to be representative of its physical properties, but small in relation to typical dimensions of the acoustic disturbance e.g. its wavelength.

If such a particle is displaced from its equilibrium position, it strikes its neighbour and thus causes that to move a similar small distance while rebounding itself. This neighbouring particle now strikes the next and so on, propagating the disturbance through the medium by successive oscillations of neighbouring elastic particles. None of these are transferred along with the wave; *it is only the energy of the disturbance that is transmitted.* The particles themselves oscillate for only an infinitesimal distance about their equilibrium positions along the direction of propagation of the sound wave, as shown in Fig. 2.1.

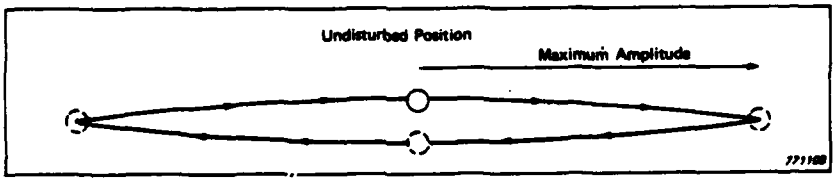


Fig. 2.1. Motion of a particle during a single cycle

The time taken for the motion to be transferred between successive particles, and therefore the velocity of propagation of the disturbance, depends on the medium's elasticity according to the following equation

$$c = k\sqrt{\frac{E}{\rho}}$$

where k is a constant
E is the modulus of elasticity of the medium
ρ is the density of the medium

For air, under normal conditions, the medium with which we will be almost exclusively concerned, this velocity is approximately 344 m/s at 20°C.

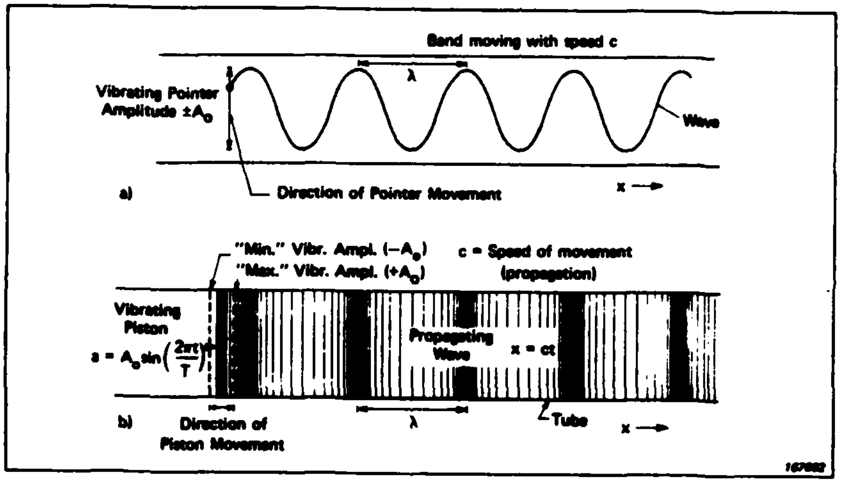


Fig.2.2. The transformation of vibrations into waves
a) By a vibrating pointer on a moving band
b) By a vibrating piston in a fluid medium

Fig.2.2b demonstrates what happens to the air along the path of propagation in an open-ended tube with a sinusoidally vibrating piston at one end. As the piston moves into the tube, the air is locally compressed and the compression is propagated along the tube at the speed of sound. After half the oscillation, the piston is about to move in the opposite direction, thus rarefying the air and propagating a rarefaction along the tube. Thus a pressure wave is transmitted at the same frequency and with the same characteristic waveform as the vibration of the piston which produced it. The speed of sound in air being fixed, the wavelength is defined only by the time interval between successive compressions, which is set in turn by the frequency of the disturbance.

Therefore,
$$\lambda = cT = \frac{c}{f}$$

Where λ is the wavelength
T is the time between successive compressions
c is the speed of sound in air
f is the frequency of the disturbance

A reference nomogram relating wavelength to frequency for the speed of sound under normal conditions is plotted in Fig.2.3.

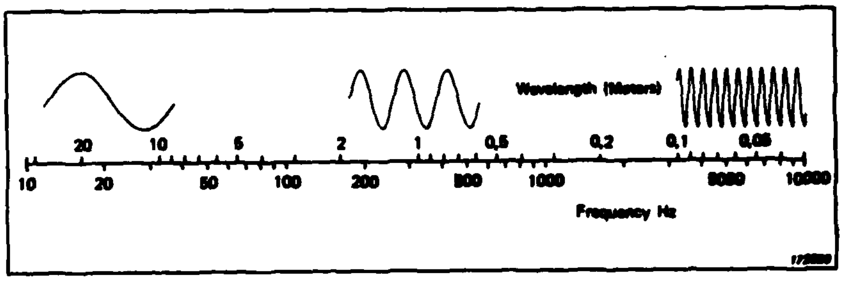


Fig.2.3. Wavelength in air versus frequency under normal conditions

We are dealing here with the simplest of all radiated waves, the plane, progressive wave, so called because it propagates away from the source in one direction only, the wavefronts always remaining parallel to each other. Because it cannot spread out into the medium, the only attenuation which is experienced is that due to transmission losses and dispersion caused by turbulence and temperature gradients within the medium itself. Although the magnitude of a sound wave can be determined in a number of different ways, it is usually more convenient to measure acoustic pressure rather than parameters such as particle displacement or velocity which are extremely difficult to measure in practice. These parameters are normally only required when measurements are to be made very close to the source in its near field. The particle velocity here is not necessarily in the direction of travel of the wave, and the sound pressure may vary appreciably at short intervals along the direction of propagation. Under these conditions the acoustic intensity is not simply related to the mean square of the sound pressure. In the far field, however, this relationship is true, and, because sound pressure level is an easy parameter to measure in practice, it has become the most common way of expressing the magnitude of an acoustic field.

2.2. SOUND POWER, ENERGY DENSITY AND INTENSITY

Sound Power

Any source of noise has a characteristic sound power, a basic measure of its acoustic output, but the sound pressure levels *it gives rise* to depend on many external factors, which include the distance and orientation of the receiver, the temperature and velocity gradients in the medium, and the environment. Sound power on the other hand is a fundamental physical property of the source alone, and is therefore an important absolute parameter which is widely used for rating and comparing sound sources.

Sound-energy Density

The acoustic energy contained in a unit volume of the medium is a fundamental parameter of any type of acoustic field. It is termed the energy density and is related to the acoustic pressure by the following equation

Energy Density $$D = \frac{p^2_{rms}}{\rho c^2}$$

Intensity

The intensity, the acoustic energy flowing through unit area in the sound field (perpendicular to the direction of propagation of the wave if the field is not diffuse), in unit time, is different for various types of acoustic field.

For a free field in which the sound wave arrives only from the direction of the source

$$I = \frac{p^2_{rms}}{\rho c}$$

For a diffuse field, such as occurs in an ideal reverberant room, in which there is equal probability of sound arriving from any direction, the net intensity is zero. However, the intensity of sound passing through a plane of unit area from one side only is

$$I = \frac{p^2_{rms}}{4\rho c}$$

ρc is called the characteristic acoustic impedance of the medium, which for air at 20°C is 407 rayls (Kg m^{-2} sec^{-1})

2.3. THE PLANE SOURCE

Consider (see Fig. 2.4.) an elemental tube of the medium, with unit cross-sectional area and a length equal to the distance travelled by the sound wave in one second, i.e. numerically the speed of sound (c). If a piston source of power W is constrained by hard walls to radiate all its power into the elemental tube to produce a plane wave, the tube will contain a quantity of energy numerically equal to the power output of the source. Assuming no other losses, the intensity, i.e. the acoustic energy flowing through unit area anywhere along the tube in unit time, is independent of the distance from the source and numerically equal to its sound power. Apart from duct systems, plane waves and plane sources are rarely encountered in normal noise measurement situations.

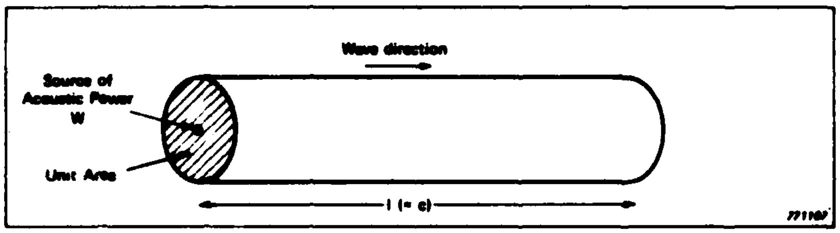


Fig. 2.4. Acoustic Radiation into an elemental tube

2.4. THE POINT SOURCE

Sound sources can be considered as point sources if their dimensions are small in relation to their distance from the receiver, and many common noise sources, including industrial plant, aircraft, and individual road vehicles can normally be treated in this way. As shown in Fig.2.5 the ideal point source can be considered to produce a series of spherical wavefronts resulting from successive disturbances at the point source. For a pure sinusoidal disturbance, the distance between wavefronts representing the successive peak pressures will of course be the wavelength, a fact which is important when considering the effects of reflections within the sound field. As shown in Fig. 2.6., the sound energy spreads out equally in all directions so that as it travels further and further from the source its energy is received on an ever larger spherical area. If the medium is assumed to be non-dissipative then the entire power output of the source passes through a spherical shell of radius r. The intensity is therefore the Power of the source divided by the area of this shell. Thus we have

$$I = \frac{W}{4\pi r^2}$$

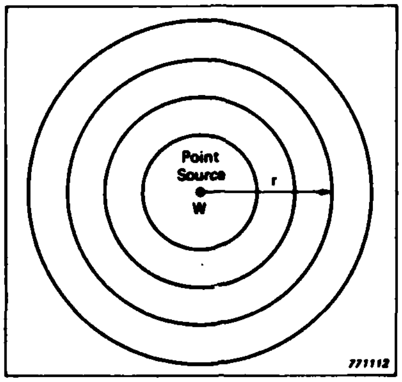


Fig. 2.5. The propagation of spherical wavefronts from a point source

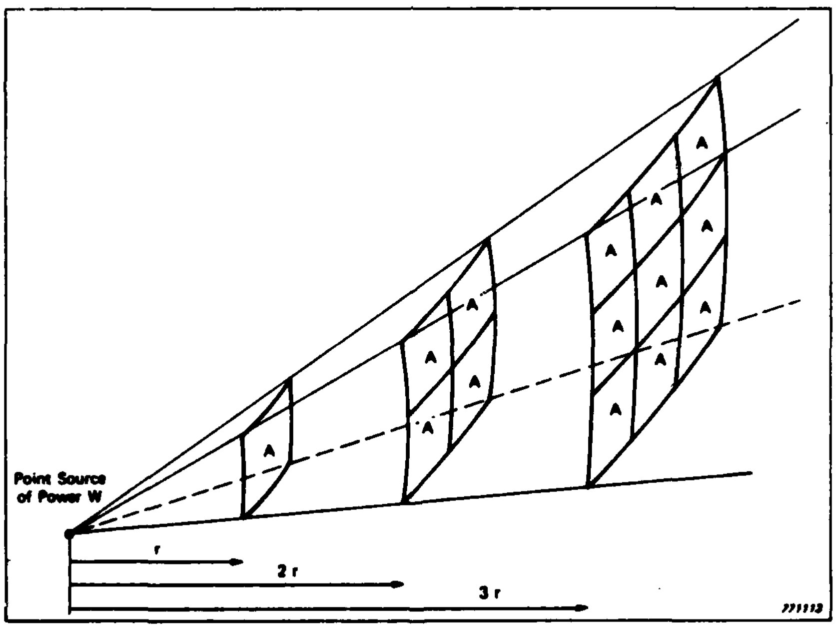


Fig. 2.6. The dispersion of sound from a point source

It can be seen that the intensity is inversely proportional to the square of the distance between source and receiver, i.e. it attentuates 6 dB per doubling of distance.

2.5. THE LINE SOURCE

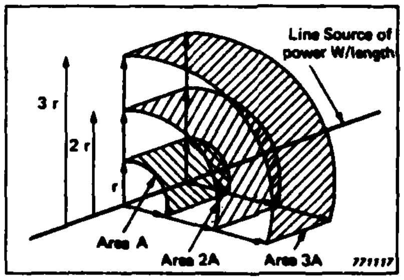


Fig.2.7. The dispersion of sound from a line source

A line source may be continuous radiation, such as from a pipe carrying a turbulent fluid, or may be composed of a large number of point sources so closely spaced that their emissions may be considered as emanating continuously from a notional line connecting them. In this category are included such factory sources as closely-spaced machines and conveyors, and two extremely important sources of environmental noise, namely roads and railways. A road which has a traffic flow high enough to be a noise nuisance can usually be considered as a line source rather than a succession of single events. Railways are often treated as line sources at the distances from the track which are usually the most important from the point of view of community annoyance. Very close to or very far from the track, the field is rather more complex. Consider the diagram in Fig. 2.7. of part of an infinite line source which has a constant power per unit length. The wavefront spreads out from the line in only one dimension perpendicular to its direction of travel, so that any two points at the same distance from the line are on the same wave front and have the same properties. The wavefronts therefore form concentric cylindrical surfaces about the line source as axis. The energy released from a unit length of the source in unit time passes through the same length of cylindrical surface at all radii. The intensity at a given radius is therefore the power emitted by this element, divided by the area of the cylindrical elemental surface. Thus:

$$I = \frac{W}{2\pi r \times 1}$$

The intensity is therefore inversely proportional to the distance from the source i.e. it attenuates 3 dB per doubling of distance.

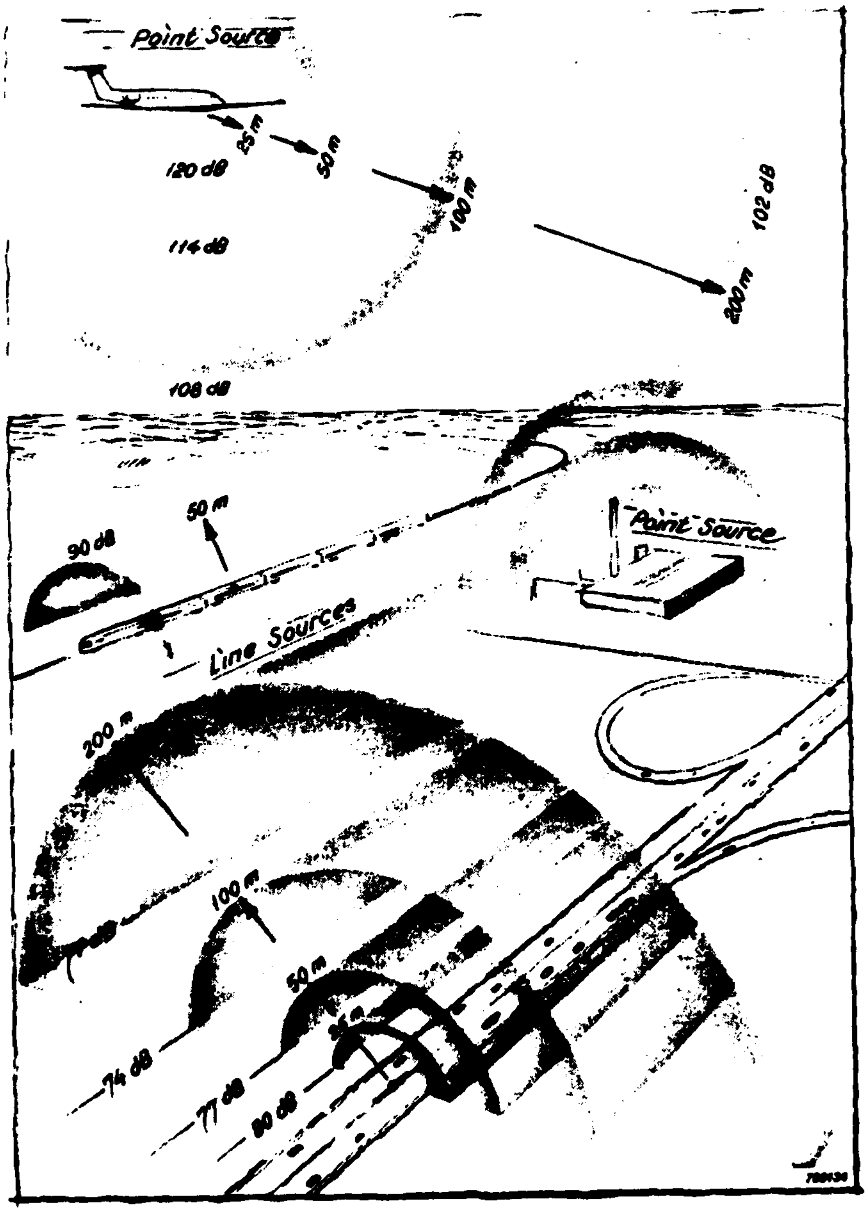


Fig. 2.8. Attenuation from point and line sources

2.6. PROPAGATION OF SOUND IN AIR

In addition to the reduction in intensity by distance, discussed in the previous sections, there are many other factors which can significantly affect the propagation of sound in a real medium like the atmosphere. Velocity and temperature gradients alter the direction of the wave, turbulence distorts it, and viscosity causes absorption. This latter effect is far greater for high than for low frequencies, so the atmosphere tends to act as a low pass filter, attenuating high frequencies, and thus distorting the frequency spectrum of a noise, as well as reducing its strength and changing its propagation path. In addition, most measurements are made near ground level where people live and work and where noise is invariably received and, with the notable exception of aircraft noise, produced. For this reason the reflection and absorption of the ground under the path between source and receiver is very important, and must be taken into account as a matter of course whenever studying the transmission of outdoor noise.

2.7. THE EFFECTS OF WIND

The atmosphere is in a state of continuous motion over the Earth's surface and is also a real fluid with all the normal physical properties including viscosity. Because the air is viscous the velocity of molecules at the ground must be zero and a boundary layer is formed near the surface, in which the wind speed gradually increases with height until the speed of the main air mass is attained. This region may be as much as several hundred meters thick so it can, and does, affect measurements made of most noise sources. When a sound wave impinges on a layer of air which has a different speed, the wave's direction of travel changes, as represented by the sound "rays" and vector constructions in Fig.2.9. This happens because the speed of sound depends only upon the medium in which it is propagated, so any movement of that medium must necessarily impose a similar movement on the sound wave as seen from the ground. If it has a component in the same direction as the wind, the ray representing the direction of propagation is therefore refracted towards the interface between the two different velocity regions when entering that with the higher speed, or away from the interface when entering a region of lower speed. The effects are simply reversed if the direction of sound propagation is opposite to that of the wind. Although the lower atmosphere is not a series of discrete layers with fixed velocities, but a transition region in which the velocity changes continuously with altitude, it can be seen from this simple approach how the sound rays will be continuously refracted as they progress through the boundary layer.

The overall effect as far as a stationary observer on the ground is concerned, is to bend the downwind sound rays back towards the Earth and bend the upwind rays away from it as shown in Fig. 2.10. A region of noise

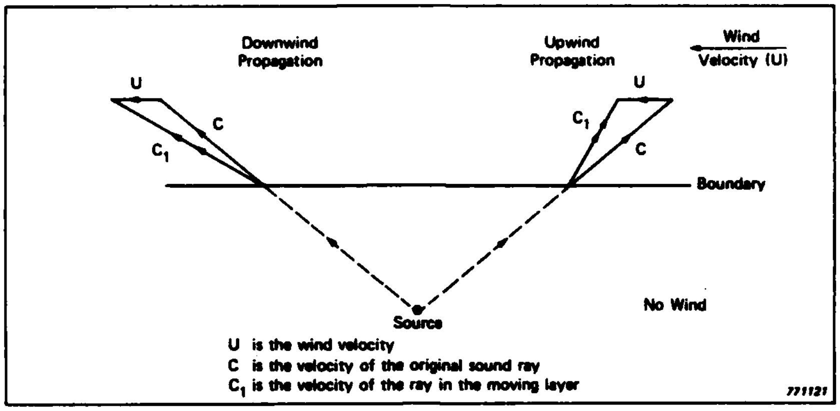


Fig.2.9. Sound propagation across a boundary between layers with different velocities

reinforcement is therefore formed downwind of the source and a sound 'shadow', a region of reduced intensity, occurs on its upwind side. Refraction effects can only occur because there is a wind gradient, *i.e.* because the wind speed varies with altitude, and are not the result of sound being convected along by the wind. The magnitudes of changes in sound intensity which can be attributed to this phenomenon are dependent only on the rates of change of wind speed with altitude. Attenuations in the shadow region may be as high as 30 dB but the increases which are due to reinforcement downwind of the source are usually rather less.

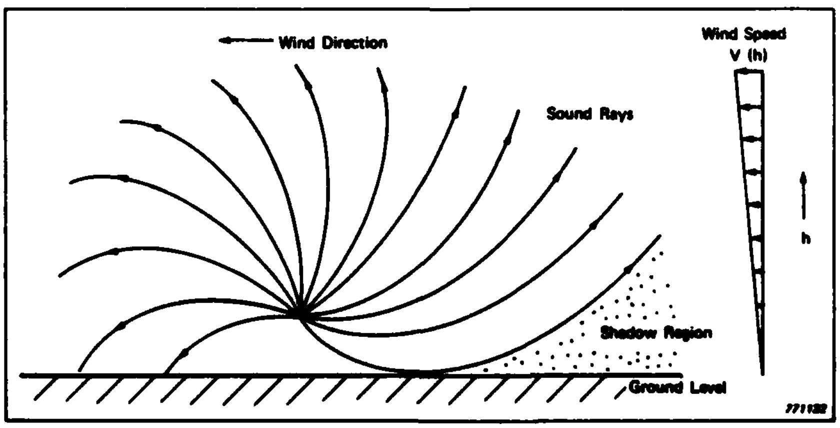


Fig.2.10. Sound refraction in a boundary layer

2.8. TEMPERATURE GRADIENTS

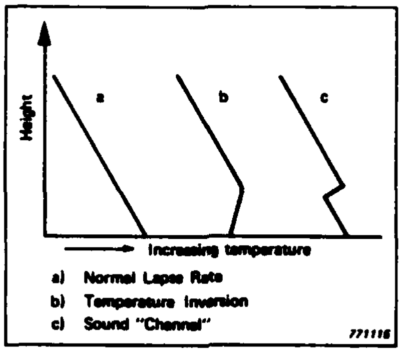


Fig.2.11. Typical atmospheric temperature gradients

The velocity of sound in air increases with temperature, and in a normal atmosphere the temperature itself decreases with height as in Fig. 2.11(a). A rising sound ray, on entering a layer with a lower temperature, undergoes a reduction in propagation velocity and is refracted away from the interface between the two layers. The result is that, in the absence of wind, the rays are continuously bent away from the ground surface as shown in Fig. 2.12(a) and a shadow region is formed beginning at a distance from the source which depends on the strength of the temperature gradient. As with wind gradients, the effects of temperature gradients are made less distinct by the inhomogeneity of the atmosphere in its normal state, with turbulence and local heat exchange scattering sound into the shadow regions.

Sometimes, however, the temperature gradient near the ground is positive, i.e. the temperature increases with height up to a point where it reverts to the normal lapse rate as in Fig.2.11(b). This situation is called a temperature inversion and leads to effects opposite to those described above for a normal lapse rate. A sound ray becomes refracted downwards towards the ground as it progresses through the warmer layer of air, reinforces the sound field at surface level around the source, and, as Fig.2.12(b) shows, no shadow region will be formed.

A double temperature gradient such as that in Fig.2.11(c) is rarely encountered, but can trap slightly-inclined sound waves in the inversion layer and channel them over considerable distances with only low attenuation.

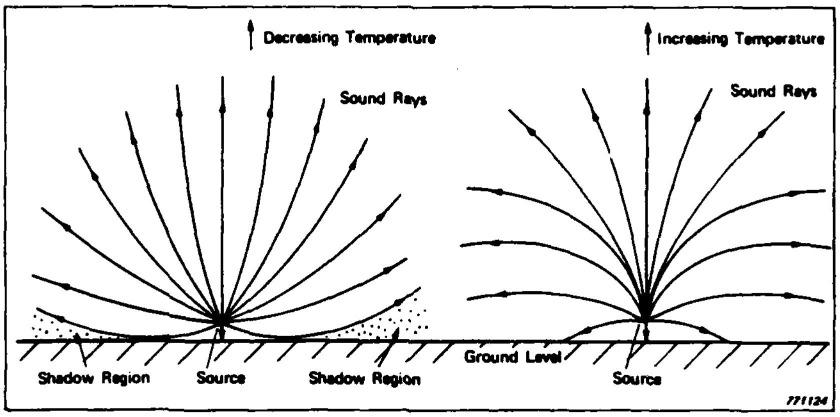


Fig.2.12. Refraction of sound in an atmosphere with
a) a normal lapse rate
b) an inverted lapse rate

2.9. HUMIDITY AND PRECIPITATION

The absorption of sound in air varies with frequency, humidity and temperature in an extremely complicated fashion; the only general trend being that it is higher at high frequencies, and shows a tendency to increase with temperature but decrease at higher relative humidities. If it is imperative to include these effects when carrying out research into distant noise sources, the current literature on the subject, and the available tables which contain the relationships between all the relevant parameters, should be consulted. The oft-mentioned ability of sound to "carry" in fog or light precipitation of any kind is not due to any changed physical property of the medium which is conducive to better propagation. Reduced human activity and still air conditions often combine to produce a lower than normal background noise level during these periods.

2.10. ABSORPTION BY NATURAL FEATURES

If the ground surface below a sound wave is perfectly flat and reflecting, the wave would propagate without any excess attenuation over that attributable to the spreading of the acoustic energy throughout an ever increasing volume. Even a man-made hard surface such as concrete is not perfectly reflecting, however, and most natural ground cover has significant absorption. This causes a significant reduction in intensity, which is most marked when source or receiver, or both, are near the ground and relatively distant. As would be expected, the attenuation is greater for high frequencies than for lower ones and depends to a large extent on the effective "roughness" of the surface, i.e. the ratio between the wavelength and the dimensions of the irregularities of the ground. The values are, therefore, low for ordinary grassland, but may rise to as much as 20 dB per 100 metres for long grass, corn or low shrubs and trees.

2.11. REFLECTION

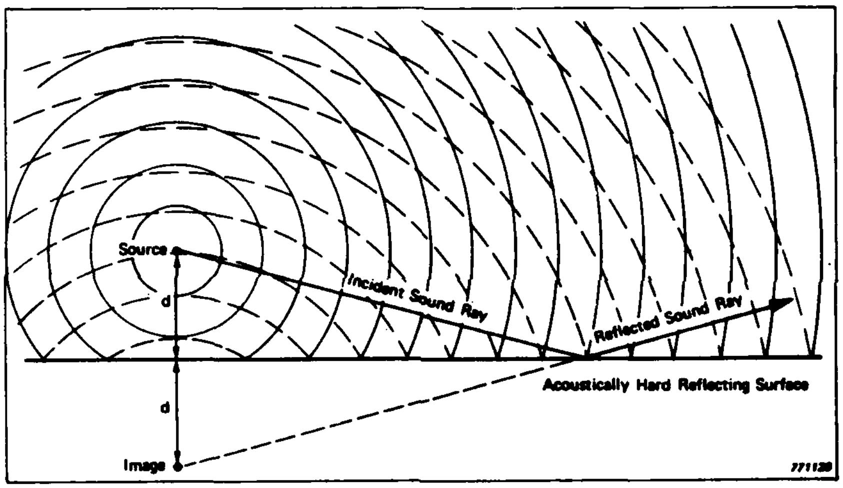


Fig.2.13. Reflections from a plane surface

When sound waves come in contact with a surface, part of the energy is reflected from it, part is transmitted through it and part is absorbed by it. The instantaneous sound pressure at any point in the field is therefore due to the direct radiation from the source, and the sound arriving indirectly after one or more reflections from the surfaces, where a part of its energy, however small, is absorbed. If absorption and transmission are low, and therefore most of the sound energy incident on the surface is reflected, it is said to be acoustically hard, and can be considered to reflect sound in much the same way as a mirror reflects light. The ray reflected from a flat rigid surface then takes up the position as shown in Fig. 2.13 and the sound ray and wave fronts can be considered as coming from the image. The reflected wave fronts and those arriving directly from the source reinforce or cancel each other where they cross, giving rise to problems when making noise measurements in the presence of reflecting surfaces such as hard ground, roads, and building facades.

The effect of curved surfaces, parallel flat surfaces, and corners, on the sound field, is shown diagrammatically in Fig. 2.14. If the reflecting surface is curved then the rays will be focused when the surface is concave, and dispersed when convex. A ray entering a right angled corner will be reflected from it, after two reflections, back along a path different from, but parallel to, its incoming one. Parallel surfaces cause two important effects. Firstly, the formation of standing waves, which occur at frequencies such that an integral number of half wavelengths occur between the two surfaces, leading to a very large variation in sound pressure from node to antinode. The second effect, flutter echo, is caused by the continuous and regular reflection of a pulse from parallel surfaces with low absorption. These phenomena are undesirable in architectural acoustics (concert halls, lecture rooms etc.) and in acoustic testing chambers, where uniformity of the sound field is generally required.

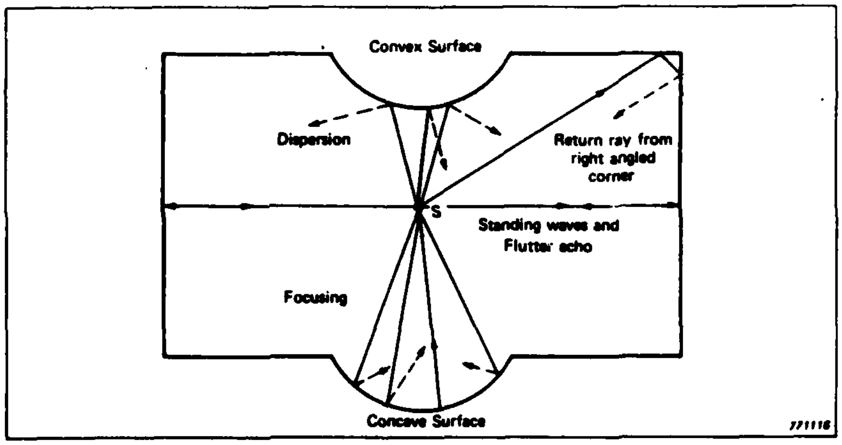


Fig. 2.14. Reflections from surfaces of various shape

In any enclosed sound field there will be a region near the noise source in which its dimensions have an important effect, a region further away in which it is the direct sound which is dominant, and beyond this a region dominated by the reverberant sound, which builds up by continual reflection until the energy produced by the source is just balanced by the energy absorbed by the room surfaces, and an equilibrium state is reached. These regions are shown in Fig. 2.15. The "near field" is usually avoided in making noise measurements because simple relationships between the sound intensity and

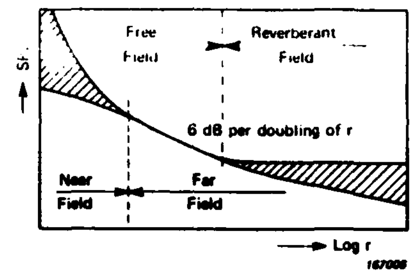


Fig.2.15. Sound pressure variation in a room, with variability indicated (F.M. Wiener)

other physical parameters, such as pressure and particle displacement, do not exist there. Measurements are usually only made here when detailed information about the radiation characteristics of the source are required for research and development purposes in the laboratory. The "far field" consists of two parts, the free field, where sound, as the term suggests, behaves as if in the open air, without reflecting surfaces to interfere with its propagation, and the reverberant field, which is dominated by reflections and therefore occurs in most enclosures. A diffuse field: i.e. one in which a large number of reflected waves from all directions combine so that the average energy density is the same throughout the field, is desirable for sound power measurements and for determining the sound insulation properties of materials. Reverberant rooms used for these measurements are often constructed as in Fig.2.16 with highly-reflecting non-parallel walls, or provided with diffusers in order to achieve a suitably diffuse field.

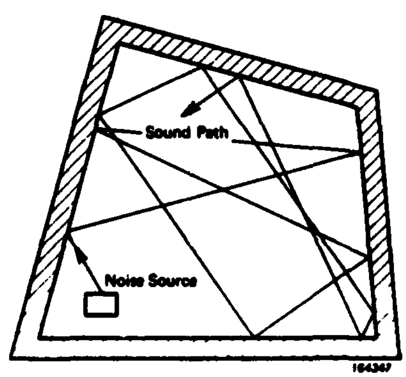


Fig.2.16. A reverberant room designed to obtain a diffuse field

2.12. ABSORPTION

Whenever a sound wave meets a surface, some small amount of its energy is lost. The absorption of a surface is a function of many parameters, including its effective roughness, its porosity, its flexibility, and in some cases its resonant properties. The efficiency of an absorbing surface is expressed as a number between zero and 1, called the absorption coefficient. Zero represents no absorption, i.e. perfect reflection, which is never encountered in practice, and 1 represents perfect absorption. Most mechanisms of absorption are frequency dependent, so the spectrum of the noise concerned has to be known to judge its effect, both in rooms and in the open air. Absorption techniques really come into their own with regard to Architectural Acoustics and the control of reverberation and diffusion in halls, rooms and offices. Absorbent materials can, however, be put to good use to reduce overall levels in noisy factories, and to provide acceptable conditions near particularly noisy machinery by reducing reflected noise from adjacent hard surfaces.

2.13. DIFFRACTION

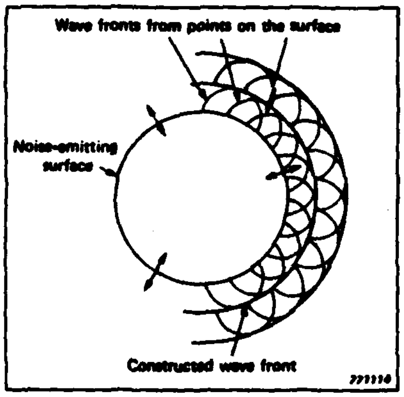


Fig.2.17. Huygen's method of wavefront construction

When a sound wave encounters an obstacle which is small in relation to its wavelength, the wave passes round it almost as if it did not exist, forming very little shadow. But, if the frequency of the sound is sufficiently high and the wavelength is therefore sufficiently short, a noticeable shadow is formed. These phenomena can be explained by first introducing Huygen's method of wavefront construction, which states that a source may be considered as an infinite number of point sources covering its surface, and radiating in all directions. At an instant in time, each point emits a sound wave and these combine to form an overall wavefront as in Fig. 2.17. Similarly, each point on a wave front can be considered as a new sound source, so the next position of the wave front can be constructed from the last. Extending this concept to the two cases of Fig. 2.18(a) and 18(b) we can see what happens when the wave fronts from a distant source impinge on the edge of, or an opening in, an otherwise infinite wall.

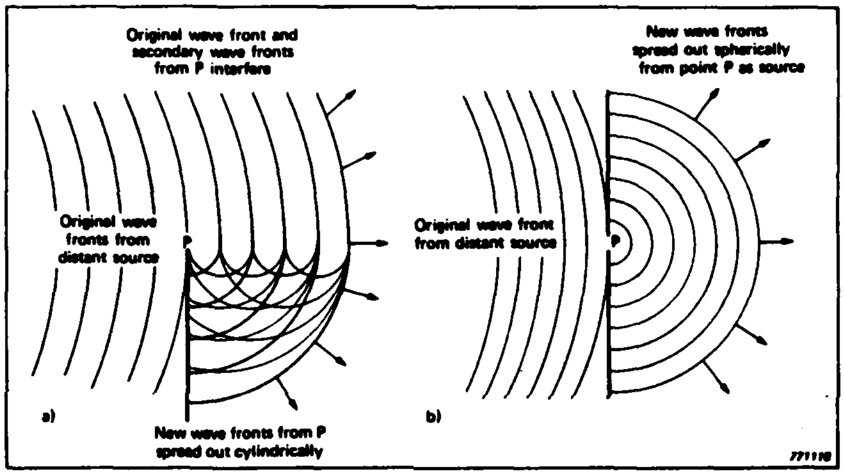


Fig.2.18. Effects of diffraction at low frequencies

In the case of the situation in Fig.2.18(a) the wall edge can be considered as a source of secondary wavelets radiating away from it in all directions according to Huygen's principle. These secondary wavelets combine to form wavefronts which spread out cylindrically in the quadrant behind the wall, in the so-called shadow region. For the second case the opening becomes, in effect, a new point source of sound, radiating hemispherically into the space beyond the wall, but with a lower intensity (depending on the size of the opening) than the incident sound.

A large ratio of wavelength to obstacle size causes the diffraction pattern as shown in Fig.2.18(a) and 2.18(b). A small value leads to the formation of a more distinct shadow behind a barrier, Fig.2.19(a), or a beam of sound through an opening as shown in Fig.2.19(b). The greatest attenuation behind a barrier occurs if the angle between the ray from the source to the barrier top, and the line from there to the receiver, is as small as possible. Practically, this means that the barrier should be as near as possible to either the source or the receiver for greatest effect. When taking measurements of noise sources in the field, unobstructed situations are always to be preferred unless the barrier effect is of direct interest.

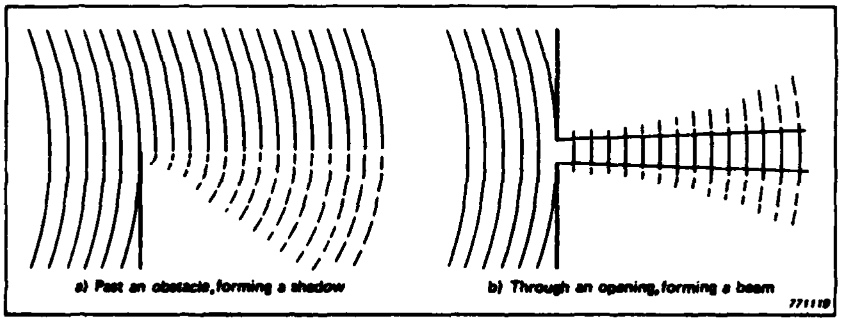


Fig. 2.19. Effects of diffraction at high frequencies

2.14. SCALES FOR NOISE — THE DECIBEL

Propagation through any elastic medium takes place in the form of a wave, and the most important quantity characterising its magnitude is its root mean square amplitude, A_{rms}. Suitable units and scales for expressing this value must now be considered. Normally, the sound pressure rather than the intensity of a sound field is the parameter used, expressed as force per unit area in units of dynes per square centimeter (bar) in the CGS system or in units of newtons per square meter (Pascals) in the S.I. system. As the Pascal has now been internationally adopted as the unit of pressure, it will be used exclusively throughout this book.

The normal method of measuring pressure on a linear scale unfortunately gives rise to certain problems when related to the performance of the human ear. The quietest sound at 1000 Hz which can be heard by the average person has been found to be about 20 μPascals and this value has been standardised as the nominal hearing threshold for the purpose of sound level measurements. At the other end of the scale the threshold of pain occurs at a sound pressure of approximately 100 Pascals, a ratio of more than a million to 1. The direct application of linear scales to the measurement of sound pressure would therefore lead to the use of enormous and unwieldy numbers.

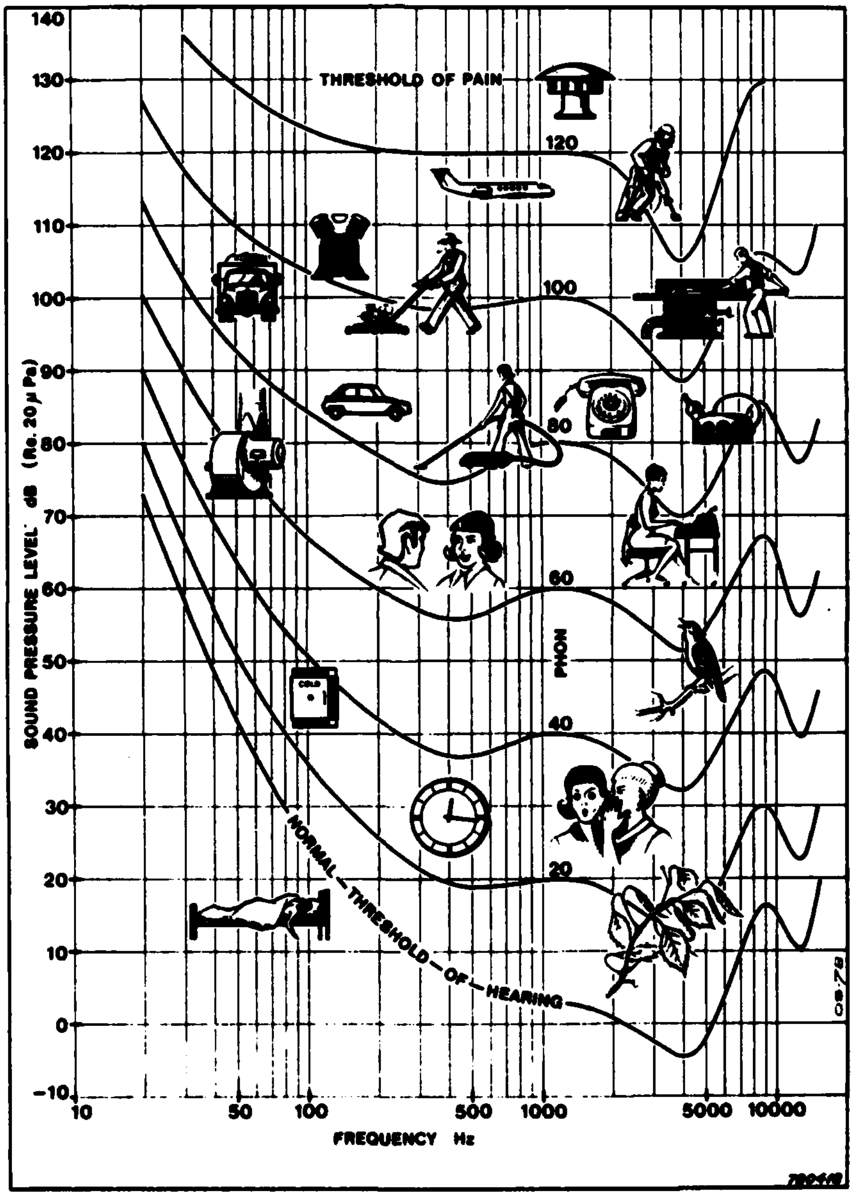


Fig. 2.20. Typical sound pressure levels of common noise sources

Additionally, the ear responds not linearly but logarithmically to stimulus. For these reasons it has been found more practical to express acoustic parameters as a logarithmic ratio of the measured value to a standard value. This reduces the numbers to manageable proportions and the resulting unit, called the Bel (after Alexander Graham Bell) is defined as the logarithm to the base ten of the ratio of two acoustical powers, or intensities. But, this unit was found in practice to be rather too large, and a unit of one tenth of a Bel, the decibel, is now in general use. As the acoustic intensity, the power passing through a unit area in space, is proportional in the far field to the square of the sound pressure, a convenient scale for acoustic measurements can be defined as

$$\text{Sound Pressure Level} \quad Lp = 10 \log_{10}\left(\frac{p}{p_0}\right)^2 = 20 \log_{10}\frac{p}{p_0} \qquad (1)$$

where p is the sound pressure being measured. p_0 is the reference sound pressure, usually 20μPa. and the word level is added to sound pressure as an indication that the quantity has a certain level above some predefined reference value.

Any measurement may be expressed in decibels, whatever its units, as long as the absolute reference value for the unit used in the logarithmic ratio is quoted. Use of the decibel scale thus reduces a dynamic range of sound pressures of a million to 1 to a more manageable range of sound pressure levels of only 0 to 120, zero indicating the reference minimum threshold and 120 the approximate threshold of pain. This is far more convenient and easier to deal with as the values lie within a range easily conceived by the layman and one unit, i.e., 1 decibel is about the smallest value of significance. The illustrated graph of Fig.2.20 shows many well-known sounds appropriately placed with regard to the sound pressure level at which they are normally heard and their major frequencies.

Acoustic Power is also usually measured in decibels because of the enormous range of powers encountered in typical noise problems. The power level is defined as ten times the logarithm to the base ten of the ratio of the source power to the reference power, usually taken as 10^{-12} watt, mathematically this becomes

$$\text{Sound Power Level} \quad L_W = 10 \log_{10}\frac{W}{W_0} \qquad (2)$$

where W is the power emitted
and W_0 is the reference power (10^{-12} watt).

The approximate power outputs of a range of a few regularly encountered noise sources are indicated in Fig. 2.21. This demonstrates well the problems of magnitude and dynamic range which are always involved when making noise and acoustic measurements.

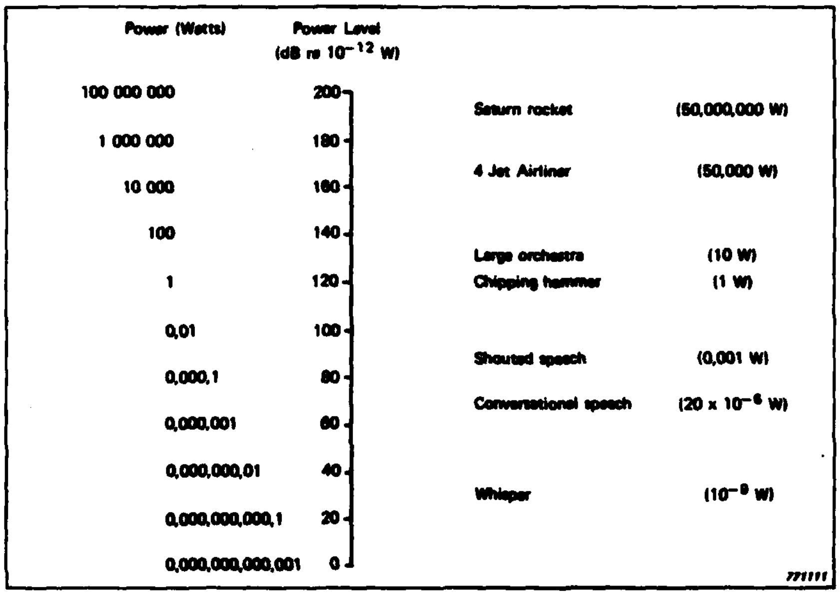


Fig. 2.21. Sound Power output of some typical noise sources

Dealing with Decibels

The following short table shows the subjective effect of changes in noise levels.

CHANGE IN LEVEL dB	SUBJECTIVE EFFECT
3	just perceptible
5	clearly perceptible
10	twice as loud

Several important facts must always be borne in mind when dealing with decibel quantities, but if these are fully understood then their use and manipulation should cause no more problems than the more familiar linearly expressed quantities. Zero decibel level does not mean an absence of noise, it merely implies that the level in question is equal to the reference level. One of the most important concepts which must be grasped firmly by newcomers to noise measurement is that, because of the logarithmic units, normal addition and subtraction cannot be used directly on decibel quantities. Two sound sources, each producing a sound pressure level of 60 dB when measured in the absence of the other, will not produce 120 dB when both are emitting at the same time. To arrive at the correct level one must consider the two instantaneous sound pressures from the two sources at a point in space. If these two individual pressures are $p_1(t)$ and $p_2(t)$, then the total pressure is

$$p_{tot}(t) = p_1(t) + p_2(t)$$

and the mean square sound pressure, the time average of $p^2_{tot}(t)$ is

$$\overline{p^2_{tot}} = \frac{1}{T}\int_0^T [p_1(t) + p_2(t)]^2\, dt$$

therefore

$$\overline{p^2_{tot}} = \overline{p_1{}^2} + 2\overline{p_1 p_2} + \overline{p_2{}^2} \qquad (3)$$

where a bar over the term denotes a time-averaged quantity. In most cases of independent noise sources we can assume that they are not coherent and therefore that significant interference of one wave front by another does not occur, so that the time average cross-term represented by $p_1 p_2$ is zero.

then $\overline{p^2_{tot}} = \overline{p_1{}^2} + \overline{p_2{}^2}$

but $p_1 = p_2$

therefore $\overline{p^2_{tot}} = 2\overline{p_1{}^2}$

so if we have two similar sources then we have doubled the mean square pressure, and from equation (1) we have

$$\begin{aligned} SPL &= 10 \log_{10}\left(2\frac{p_1{}^2}{p_0{}^2}\right) \\ &= 10 \log_{10}\left(\frac{p_1{}^2}{p_0{}^2}\right) + 10 \log_{10} 2 \\ &= 10 \log_{10}\left(\frac{p_1{}^2}{p_0{}^2}\right) + 3 \end{aligned}$$

i.e. New SPL = old SPL + 3 dB

Doubling the number of sources therefore raises the sound pressure level by 3 dB, a further doubling to four times the number raises it by 6 dB, and so on.

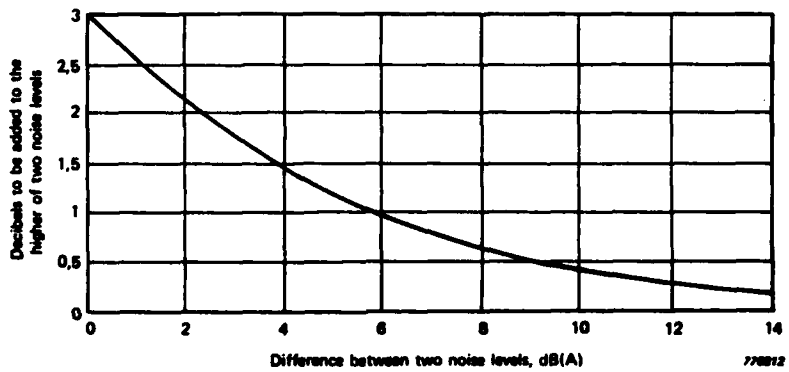


Fig. 2.22. Noise level addition chart

The addition of sound pressures of different levels and from many different sources can be carried out by first reducing the measured values to actual pressures, combining these to find the effective mean square and then taking the logarithm, as described in some detail in appendix B. A simple graph for the case of two sources only is shown in Fig. 2.22 in terms of a correction which is to be added to the highest of the two levels, depending on their difference. This may also be used to estimate the combined effect of more than two sources by summing them two at a time. If the assumption that sources of equal intensity are uncorrelated is not made, then the term $p_1 p_2$ is not necessarily zero and positions of reinforcement and cancellation will occur. In the extreme case of constructive interference between two tones of the same frequency.

$$p_1 = p_2$$

Therefore $\quad p_1 p_2 = p_1{}^2$

and equation (3) becomes $\quad \overline{p^2{}_{tot}} = 4\overline{p_1{}^2}$

Now $\quad 10 \log_{10} 4 = 6$

so the level will rise by 6 dB
For destructive interference $p_1 = -p_2$
and in this case equation (3) becomes

$$\overline{p^2{}_{tot}} = \overline{p_1{}^2} - 2\overline{p_1{}^2} + \overline{p_1{}^2} = 0$$

so the level will fall, theoretically, by ∞. In practice of course the regions of reinforcement will be a little less than 6 dB and the regions of cancellation will certainly not fall by more than 20 or 30 dB at the very most. It is recommended that appendix B is studied at this point in order to gain experience on the manipulation of quantities expressed in decibels. The ability to think clearly and effectively in terms of decibels is invaluable to the understanding of most of the Standards and the techniques involved in acoustics and noise measurement.

2.15. CHARACTERISTICS OF NOISE SIGNALS

All sound signals are characterised by certain basic physical parameters which are relatively simple for fixed amplitude and frequency signals but become increasingly complicated if the frequencies and amplitudes vary with time. Perhaps the simplest form of sound wave, with a sinusoidally varying amplitude and constant frequency, (a pure tone) is shown in Fig. 2.23. The time history repeats itself exactly with a repetition period T, corresponding to the generating frequency f, and possesses the fundamental characteristics which apply to all types of signals. Phase is of little importance in the analysis of individual noise signals, which are usually composed of many frequency components combined in random phase. However, it is a useful concept in considering reflecting or absorbing surfaces, standing waves, and the vibration of structures, where the phase difference between many signals is particularly important.

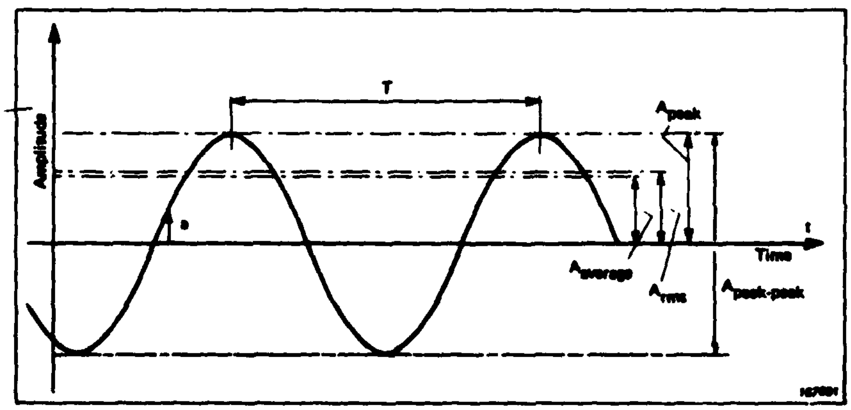


Fig. 2.23. Sinusoidal signal showing various measures of signal amplitude

The amplitude of a sinusoid may be expressed by any of the quantities shown in the diagram and all are simply related to each other in the case of this particular simple signal. The root mean square (r.m.s.) value of any signal is proportional to its energy content and is therefore one of the most important and most often used measures of amplitude. It is defined

$$A_{rms} = \sqrt{\frac{1}{T}\int_0^T a^2(t)\cdot dt}$$

Where T is the relevant time period over which the averaging takes place
and a is the instantaneous amplitude

Other measures of amplitude are

$$A_{average} = \frac{1}{T}\int_0^T |a|\cdot dt$$

and A_{peak} which is the maximum amplitude reached by the signal in the repetition period.

For any signal, a measure of its wave shape can be indicated by two factors

$$\text{Crest Factor } F_c = \frac{A_{peak}}{A_{rms}}$$

$$\text{Form Factor } F_f = \frac{A_{rms}}{A_{average}}$$

For a sinusoid *only* these values are simply related as follows,

$$A_{rms} = \frac{\pi}{2\sqrt{2}}A_{average} = \frac{1}{\sqrt{2}}A_{peak}$$

so that F_c = 1,414 (= 3 dB)
and F_f = 1,11 (= 1 dB)

Unfortunately most sounds are not sinusoids and more often than not vary both in amplitude and frequency content with time. Simple mathematical relationships between A_{rms}, $A_{average}$ and A_{peak} do not exist for these complex signals but still retain their importance as descriptors of the signal. The quantity A_{peak} is not strictly applicable to truly random noise but in practical measurements, especially when dealing with shocks, impulsive noise, and short events, it is an extremely important factor.

A signal typical of those encountered in practice is shown in Fig. 2.24(d) and clearly it cannot be described by the three simple quantities, the maximum amplitude, frequency, and, where relevant, the phase, because it is composed of more than one frequency. The signal may be viewed as a combination, however complex, of a large number of superimposed sinusoids, the concept of Fourier Analysis. A pure sine wave contains one frequency and can therefore be represented in the frequency domain as a single line as in Fig. 2.24(a). If we were to add two sine waves, one being 3 times the frequency of the other, we would obtain the distorted wave of Fig. b, which is represented in the frequency domain by two lines. Analysis of a far more complex but still periodic function, such as the square wave of Fig. c, yields an infinite number of lines in the frequency domain at the odd harmonics of the repetition frequency of the signal. The spectra of all the functions mentioned so far have been harmonically related discrete lines and are therefore termed periodic, as they repeat themselves exactly at regular and predictable intervals. Most practical noise is non-periodic, however, and contains a large number of frequency components which are not harmonically related, forming a continuous spectrum as in Fig. d. A special case of the non-periodic signal is white noise, which has a completely flat spectrum and is of particular importance in both theory and practice.

The internal combustion engine is a typical source which produces periodic noise containing many harmonics of its rotational speed. However, the noise from a vehicles tyres at high speed and that from falling water are non-periodic; both have a continuous and almost flat spectrum. In practice the majority of noise consists of a mixture of both types of signal.

The process of signal analysis is of vital importance in every branch of noise measurement, analysis and control. On one hand the frequency content of a noise affects its perceived loudness, and therefore the annoyance to which it gives rise, and also the amount of speech masking. On the other hand, the provision of an adequate acoustic environment and the reduction of noise at source or during transmission, demand a knowledge of both the source spectrum and the properties of frequency-dependent insulating and absorbing materials. This information is necessary for effective design and can only be obtained from a frequency analysis. For a fuller discussion of these techniques please refer to the companion publication "Application of Brüel & Kjær equipment to Frequency Analysis".

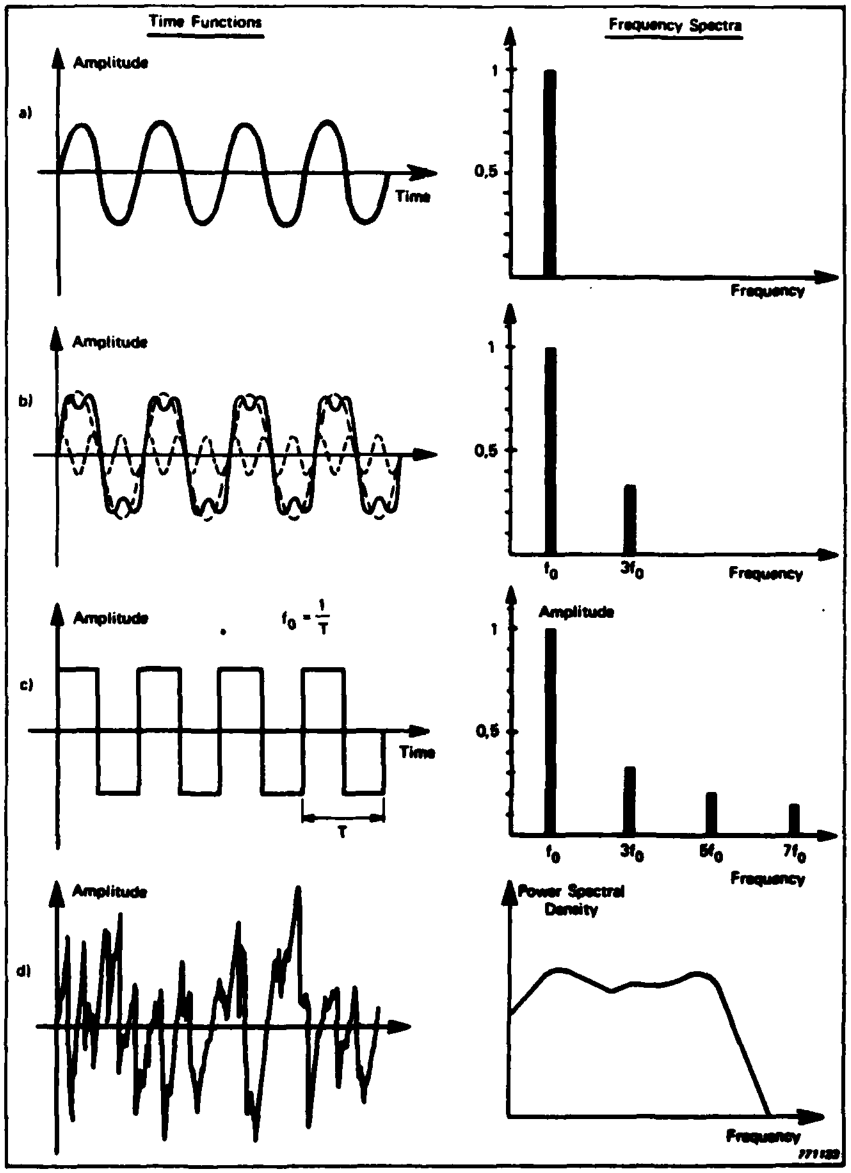


Fig. 2.24. Sound signals and their spectra
a) pure sinusoid (simple and periodic) c) square wave (complex but periodic)
b) combination of two sinusoids d) random noise (complex and non-periodic)

Emergency Warning Systems, Part I — Unclassified

PRC Voorhees, 1500 Planning Research Drive, McLean, Virginia 22102

FEMA Award EMW-C-0680; Work Unit 2234G July 1983 140 Pages

This document is Part I of a two-part document series on emergency warning systems. An overview is given for typical warning system methods. Since the majority of warning systems use sirens, a major portion of this document deals with sirens and their technical specifications. Encoder and decoders used to control such systems are discussed, along with tone alert radios, DIDS, and factors concerning attenuation.

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